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ABSTRACT

This booklet is the first in a series of three interdisciplinary units which focus specifically on the Pacific Ocean and its surrounding countries. The booklet, designed for lower secondary students, provides an introduction to the ocean environment such that students can understand the physical factors underlying issues raised by the other two units. The readings and interdisciplinary activities (science, art, social studies, English, and home economics) are presented in sections dealing with these topic areas: (1) introducing the Pacific Ocean, including countries and islands of the Pacific; (2) ocean creatures, examining plankton (drifting populations), nekton (active swimmers), benthos (bottom dwellers), seabirds, and the flow of food (food chain, food web, and food pyramid); (3) exploring the surface of the ocean, examining how objects stay afloat, early navigators, waves, currents, tides and the composition of sea water; and (4) exploring the depths of the ocean, focusing on the shape of the ocean floor (including continental margins and the deep ocean floor), characteristics of deep water (light, temperature, salinity, and pressure), measuring the depth of the ocean, and the possibility of a city beneath the sea. (JN)

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1. The Ocean

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Editors: Albert Caton
Janice Hamilton
Pamela Hewitt
Amanda Lohrey
Marguerite Wells

Designer: Bruce Irving

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Helen Connell

Susan Buel
Amanda Lohrey

One of the aims of the Pacific Circle Consortium is the development of educational materials with an international perspective, particularly materials that take into account the half of the earth's surface covered by the Pacific Ocean.

The Consortium works on the assumption that educational materials about other people and other cultures will be most accurate and genuine when developed jointly, by people from the country using the materials and people from the country being studied.

Harvesting the Ocean includes material from many Pacific countries and cultures. It has been developed and published as the result of co-operation between many people in a number of different countries. For their assistance and co-operation, and especially to Helen Connell, and to the Northwest Regional Educational Laboratory, Portland, Oregon, USA, we express our thanks.

1. The Ocean





What the Pacific Ocean was thought to be like in 1589.

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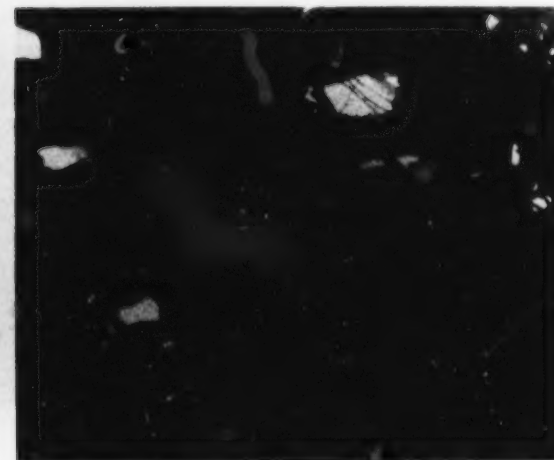
1.0 Introducing the Pacific Ocean

Did you know that we live on the only planet on which there is free water? If you were in a spaceship and looking down on Earth the first thing that would strike you is that we live on a watery planet. You can see from looking at satellite photographs that the Earth looks like one giant ocean with various land masses floating on the top.

After viewing photographs of the earth taken from outer space, David Bower, President of Friends of the Earth, observed 'there is but one ocean, although its coves have many names.'

It's no coincidence that life as we know it exists on a 'watery planet' for water is the basis of life. Life on land cannot exist without water and if there were no ocean there would be no rainfall. The rain that nourishes our land is caused by evaporation off the ocean's surface.

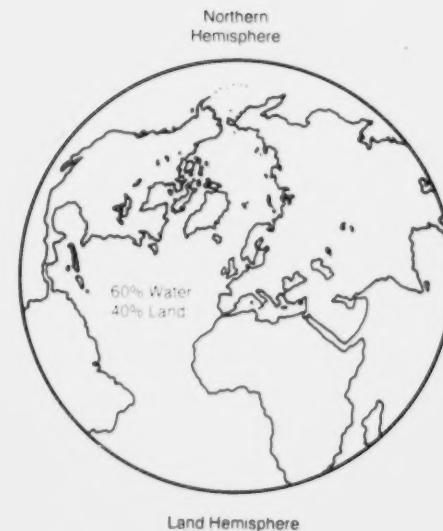
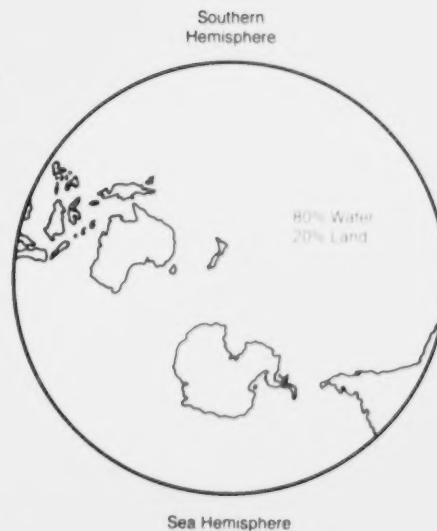
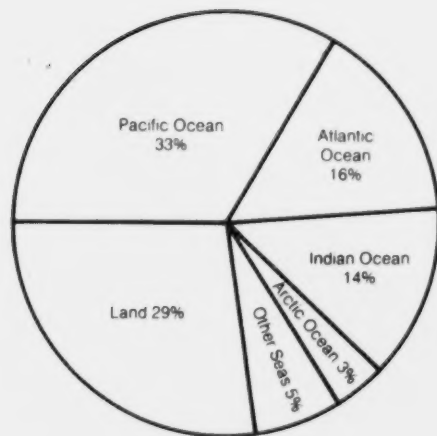
As well as water we need oxygen and this too is a vital product of the sea. The plants that live in the seas produce most of our oxygen requirements — the oxygen they give off bubbles up through the surface of the water and into the atmosphere.



Do You Know

- that almost three quarters of the earth's entire surface is covered by oceans?
- that oceans form a single water mass but are divided into different oceans by landmasses?
- that most of the earth's land is in the northern hemisphere and most of its water in the southern hemisphere?

We can know all this without ever having seen ocean water.



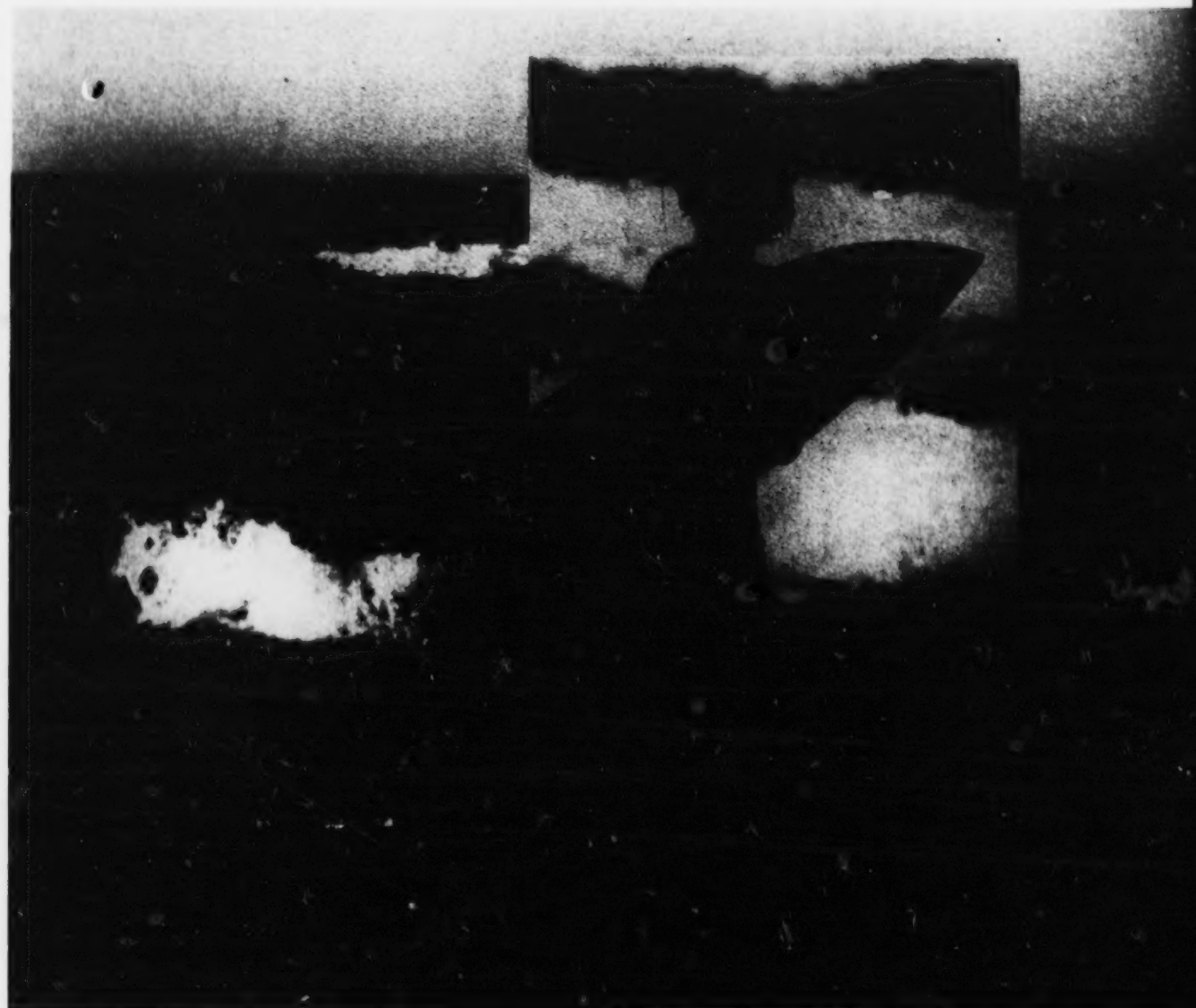
1.1 What Does the Ocean Mean to You?

The answer to that question will depend largely on **where you live**.

If you live inland it may mean an aspect of nature that you see only on a trip to the coast. It may be that you've read about the ocean or seen it on television but have never actually seen the sea.

For others of us the ocean is an everyday part of our environment. We can see it from our houses or walk to it in a few minutes.

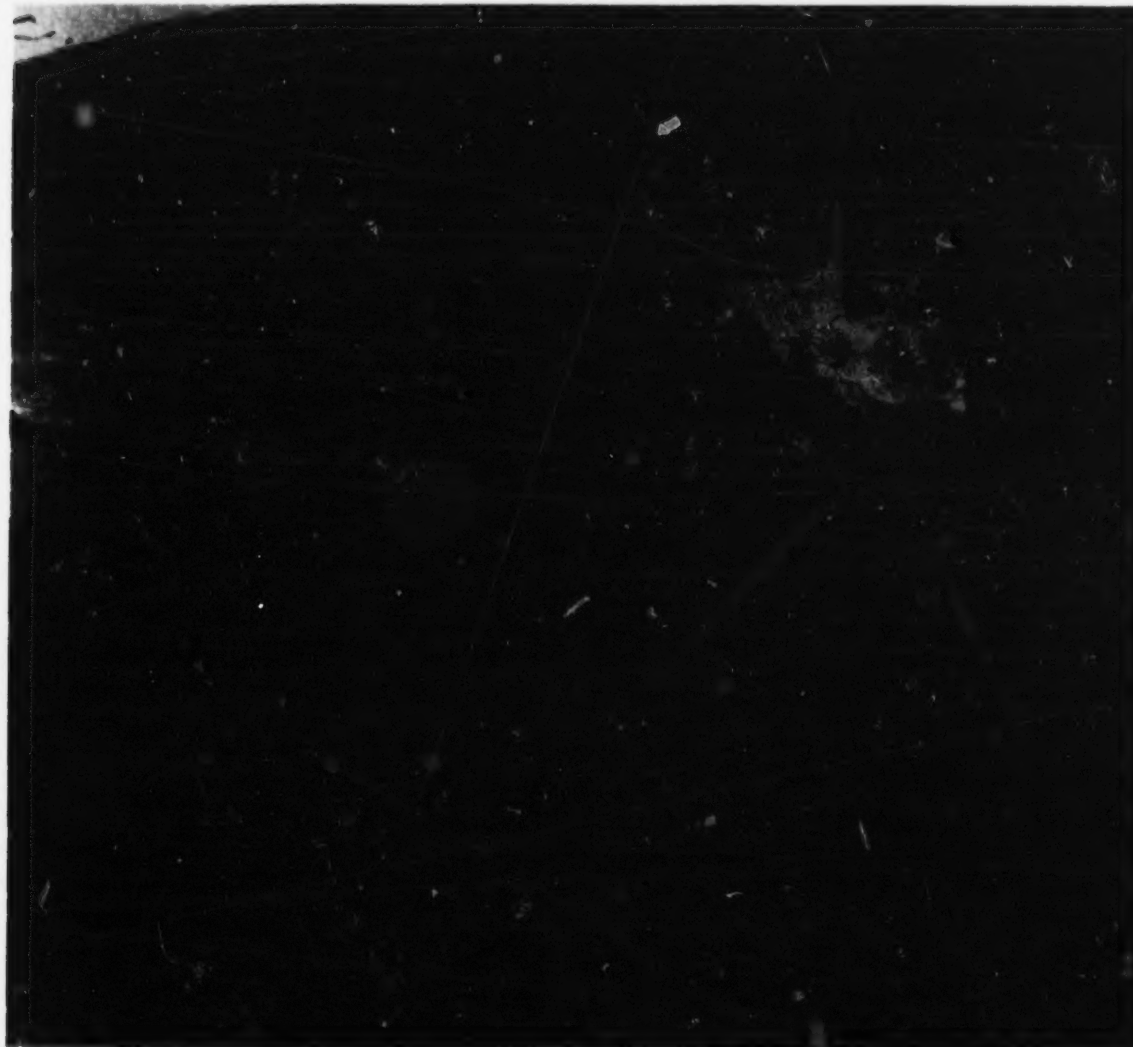
Our feelings about the ocean relate, not only to where we live, but to the **kind of society we live in**. For example, to a young girl living on the Californian coast the sea may simply be a beautiful scenic backdrop to everyday life at home and at school. It may be a source of fun at the weekends — swimming, surfing and boating. But if that girl were to move to an inland city it is not likely that her life would change all that much. The sea is not a way of life for her.



Consider now a young boy living in the Solomon Islands in the western Pacific. His whole village life and culture is directly related to the sea — the food he eats, the clothes he wears, his work, his religion and his social customs. If he were to move to an inland

city it would change his life entirely.

Although the day to day lives of a Californian girl and a Solomon Islander boy are very different, these two are united by the fact that they both live by waters of the mighty Pacific Ocean.



OCEANS OF THE WORLD

Ocean	Millions of Square Kilometres	Width	Average Depth
Pacific	181	17 700 km	4 300 m
Atlantic	83	5 800 km	3 900 m
Indian	74	9 700 km	4 000 m
Arctic	13	4 800 km	1 200 m

Note: Most map makers do not use the term Antarctic Ocean. It is simply the southern part of the Pacific, Atlantic and Indian Oceans.

As you will see from the table of the Earth's oceans, the Pacific Ocean is by far the largest. It covers 181 million square kilometres.

Look at the map opposite.

1. Where are you in relation to the Pacific Ocean?
2. What are the countries that form its boundaries?
3. Can you find **where** the Pacific Ocean joins the Atlantic, Arctic and Indian Oceans?

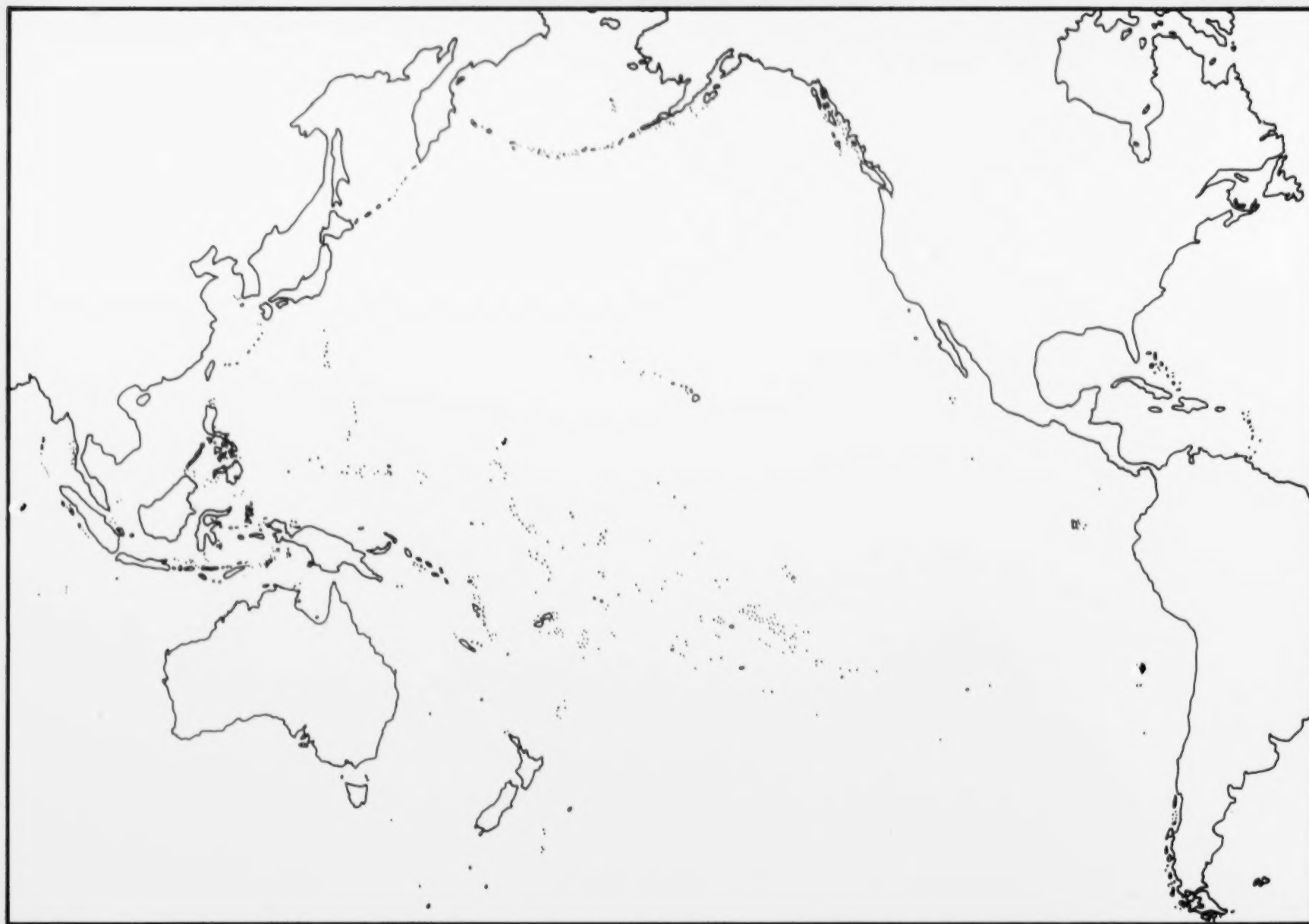
Facts about the Pacific Ocean:

- at its greatest **width**, east to west, the Pacific Ocean measures 17 700 km
- at its greatest **height**, north to south, it measures about 14 500 km
- it averages a **depth** of 4300 metres
- its **greatest depth** is 11 033 metres in the Challenger Deep of the Marianas Trench about 150 kms southwest of Guam
- the Pacific has a scatter of some 20 000 islands, concentrated on the west and south.

The name 'Pacific' means 'peaceful' from the Latin word, **pace**, meaning peace. Latin was the language of the Ancient Romans.

The Spanish explorer, Ferdinand Magellan, was the first European to sail across the Pacific, in 1520-21. He gave the ocean its name when his ships reached the calm expanse of the ocean after a period of many storms in the Straits of Magellan at the southern tip of South America.

Before Magellan came, the Pacific is thought to have been populated by several waves of migrants from the Asian mainland, who moved to many islands of the Pacific, to Papua New Guinea, Australia, New Zealand and to the Americas.



1.2 Countries of the Pacific

Many of the countries of the Pacific will be familiar to you. Some you will be hearing for the first time. The exercise set out below is designed to help you to get to know the countries of the Pacific area.

On page 11 you will find a blank map of the Pacific Ocean.

- Trace a copy of this map into your workbook.

- Now look at the stamps pictured below. Using your atlas, locate the countries named on the stamps and write the names in on your blank map.
- When you have finished, consult your atlas again. Are there any countries in, or bordering on, the Pacific Ocean that are **not** represented on the stamps pictured here?

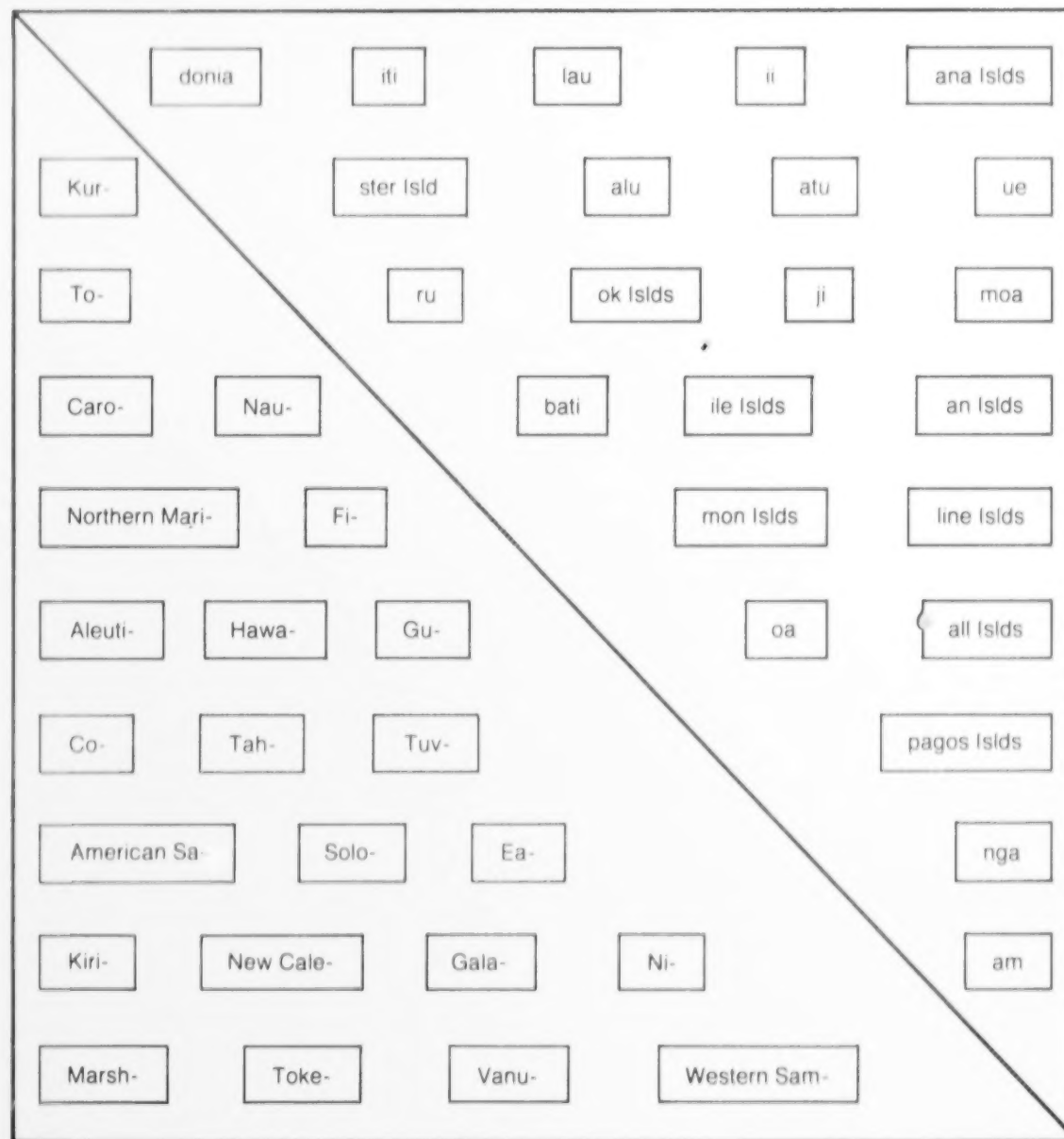


1.3 Islands of the Pacific

There are literally thousands of large and small islands in the Pacific Ocean — more islands than you will find in any other water mass on earth. In the previous section you will have noticed that in some cases the people of neighbouring small islands combine together to form one country; e.g., the Solomon Islands.

There are too many individual islands for you to remember all their names, but it is useful to be able to identify and locate the largest and most important of them. This exercise will help you to do just that.

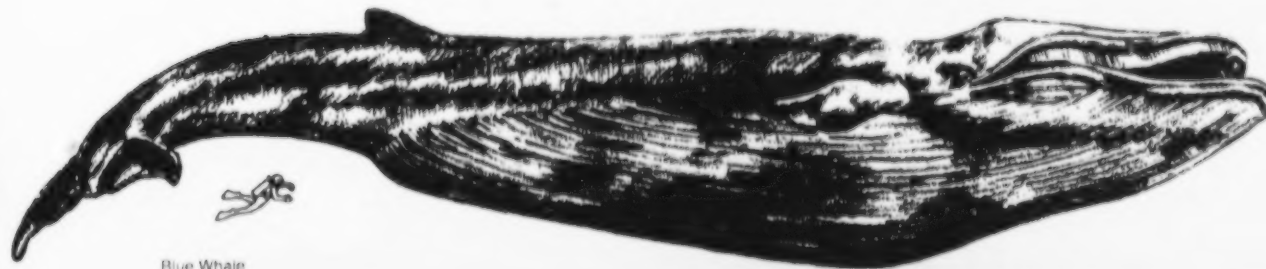
- Trace a blank map of the Pacific Ocean.
- On the page opposite you will see the names of some of the islands in the Pacific Ocean. Each name has been broken up into two parts. See if you can match up the parts to form the names of some of the Pacific Islands.
- Now plot the location of these islands on your blank map.



2.0 Creatures of the Pacific Ocean

The biggest creature that has ever lived on the earth is alive today, it is the blue whale, which grows up to 30 metres in length and 100 tonnes in weight.

The whale, the largest creature in the ocean, feeds on some of the smallest — the **plankton**. What are plankton?



Blue Whale



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2.1 Plankton — The Drifting Population

Plankton are tiny plants and animals that drift or float near the surface of the ocean. Most of them are so small you can't see them with the naked eye. Ninety percent of the plants in the sea are microscopic. Fifty percent of them are twenty micro-metres or less in width. To have an idea of how small that is you need to take into account the fact that one human hair is 100 micro-metres in width! A litre of water might contain 500 000 plants or even more. Scientists estimate that there are as many as 70 000 different kinds of plankton. Many of them grow into large fish. There are two general types of plankton, **phytoplankton** and **zooplankton**.

2.1.1 Phytoplankton

Phytoplankton, or plant plankton, are found mostly in the top 100 metres of water. They float because they are small, light and designed to float; that is, their shape helps to keep them from sinking. Although some can move very small distances of their own accord, most floating plants are carried from place to place by the ocean currents. They thrive only near the surface of the ocean because sunlight does not penetrate very far into the water.

Why do phytoplankton need sunlight?

So that they can produce their own food. They do this through a complicated process called **photosynthesis**.

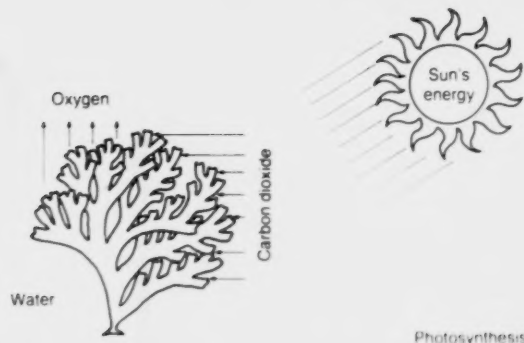
How does photosynthesis take place?

Plants contain pigments called chlorophyll. We know it best as the green in land plants. In the sea there can also be brown pigments as in kelp.

Chlorophyll enables the plants to absorb the sun's energy (light) and change it into the chemical energy of food with the help of carbon dioxide and water. This

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food takes the form of sugars and starches which the plants store for future nourishment. In the process the plants also produce **oxygen** which they release into the sea which means that we and other animals can breathe.

Most of the photosynthesis on the earth takes place in the sea. Some people believe that it's as high as 70%. Most of this takes place only in the first few metres of the water beneath the surface — that is, the depth to which light from the sun is able to penetrate.

Phytoplankton are the beginning of the **marine food web** (see p. 30). They are called **primary producers** because they produce food from sunlight, minerals and water and do not feed on other plants or animals. They themselves provide food mainly for zooplankton.

2.1.2 Zooplankton

Animals which float in the ocean are called **zooplankton**. They are called **primary consumers** because they feed on the phytoplankton.

While they are capable of movement they only travel significant distances by means of the ocean currents. Zooplankton can live at any depth of the ocean because they do not need sunlight for survival. Most of them do live near the ocean surface however, at least for some of the time in each 24 hour night and day cycle; they usually come to the surface during the night to feed on the phytoplankton and sink away from the surface during the day.

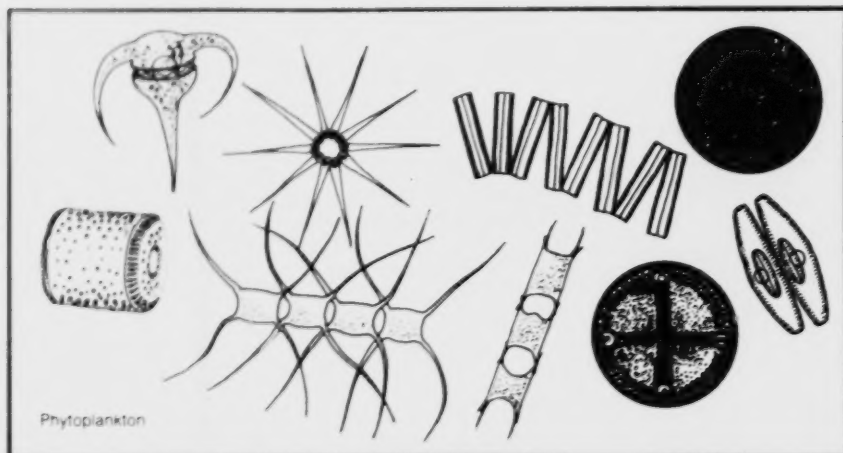
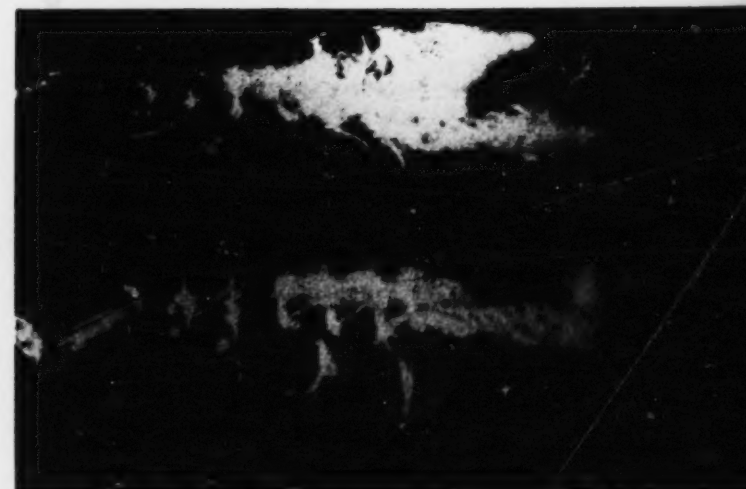
The greatest density of zooplankton occurs where the ocean is most fertile; that is where there is a large production of the microscopic phytoplankton which is their food. In the Pacific Ocean this occurs off the south and west coast of South America and in the cool temperate waters between 40° and 60° latitudes in both hemispheres.

Like phytoplankton, most zooplankton are microscopic, although, as in the case of Antarctic krill, they can be up to 8 cm long. Some float for their entire life in the ocean. These **permanent zooplankton** do not change their body shapes as adults. Other zooplankton, called **temporary zooplankton**, spend only part

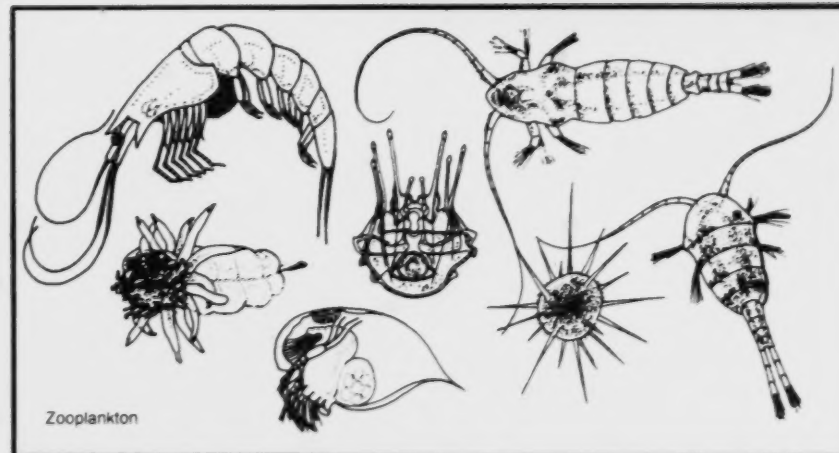
of their lives as plankton. These are the **eggs** and **larvae** of many kinds of marine animals. As plankton these animals float around but as they grow older they change their shape and become starfish, sea urchins, crabs, fish and many other animals.

Of these, probably the most important is **krill**, found in large quantities in polar waters. These are a major food source for some types of whale.

Krill



Phytoplankton



Zooplankton

2.2 Nekton: The Active Swimmers

Some animals can move through the ocean waters without depending on currents. These are called active swimming animals or nekton. Active swimming animals are larger than plankton, because they need to be strong enough to move independently of ocean currents. The nekton are the best known group of ocean dwellers, because they are

- the biggest (e.g., the shark and the whale);
- the easiest to see because they live near the surface of the ocean, often in large schools (e.g., the tuna), and are often brightly coloured;
- the ones most commonly caught by commercial fishermen and eaten by the rest of us (e.g., the mackerel and the tuna).

There are many different species of **nekton**. A species includes animals that are sufficiently alike to have had the same parents. Members of a species freely interbreed. There are also many different **categories** of nekton. A category can be made up of several species that share certain characteristics — e.g., they all live in the same environment or **habitat**.

We categorise nekton according to three basic factors:

- do they live near the surface of the ocean or at the bottom?
- do they have a backbone?
- do they breathe through gills or lungs?

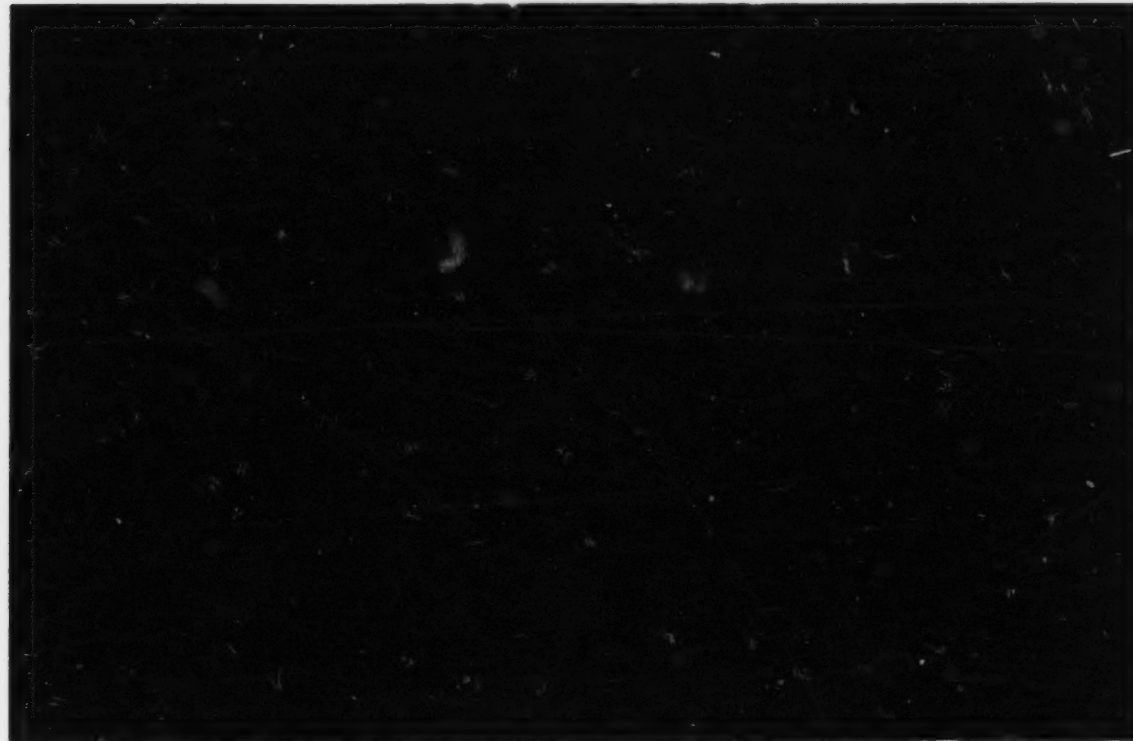
2.2.1 Habitat

Nekton that live near the surface of the ocean are called **pelagic**. Pelagic fish are excellent swimmers and often travel long distances, sometimes in **schools**, e.g., the sardine and the tuna.

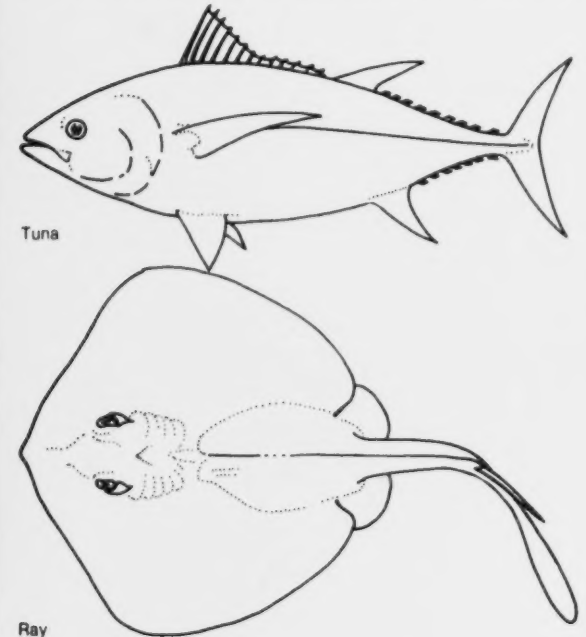
Nekton that live on or near the ocean floor are called **demersal**. Examples are skates, rays, flounder, halibut and lobsters. When we speak of the 'bottom' of the ocean floor, in this instance we mean the 'bottom' of relatively shallow water on the coastal fringe or continental shelf (see diagram on page 55).

Pelagic and demersal fish tend to differ in their appearance. This is because they have **adapted** over millions of years to the conditions of their environment.

Water is much more dense than air and tends to slow the movement of objects through it. Hence the



Flounder



Tuna

Ray

fact that we can all run faster than we can swim. To overcome this resistance of water, the more active fishes, the pelagic nekton, are **narrow and stream-lined**. Compare this with the sole or the flounder that lives on the bottom of the sea. These fishes are greatly flattened and can swim with ease along and close to a flat bottom as they search for food. Being flat enables them to hide quickly on the sand or mud. But their shape is not so good for rough or rocky surfaces where swimming agility may be important. They are not usually found in these areas. This characteristic flattening of the body in flounder is an example of 'adaptation'.

2.2.2 Structure

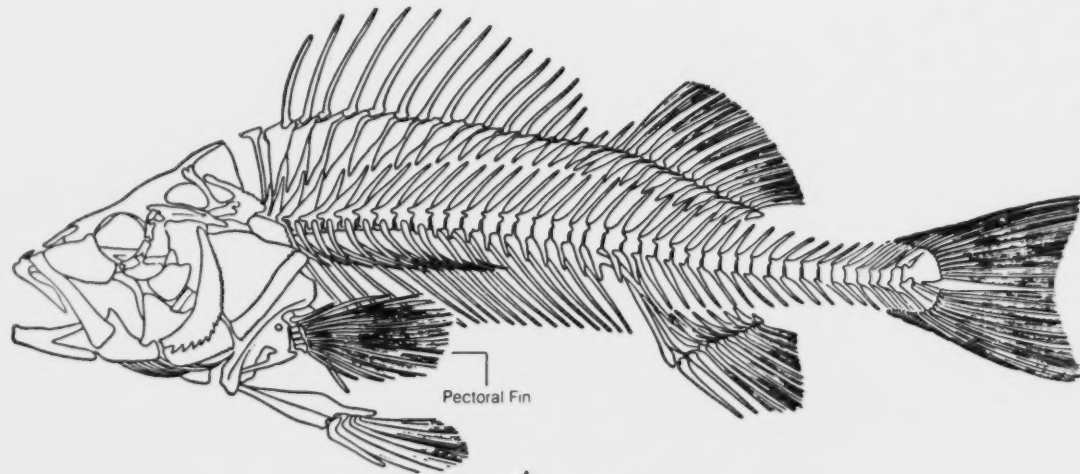
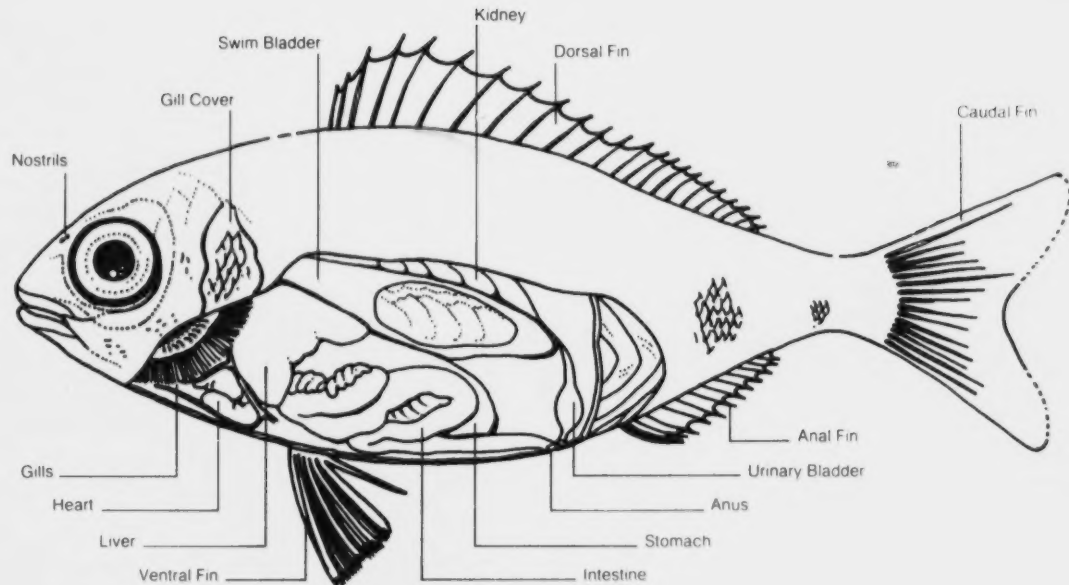
Nekton can be categorised in terms other than where they live. We also distinguish between fish with **bony skeletons** (vertebrates) and **cartilaginous** fishes. Cartilaginous fish don't have a long bony skeleton but one that is made of cartilage — a pliant, gristle-like substance that makes up the tip of our nose and makes up little 'pads' between our joints. Examples are sharks, skates and rays.

One of the most interesting categories of nekton is the **ocean mammal**. Unlike the bony and cartilaginous fish, that 'breathe' through gills (see page 18), the ocean mammals belong to the same animal group as humans and breathe through lungs.

All mammals

- have backbones,
- are warmblooded,
- have a diaphragm which helps to push air into the lungs, and
- their young are born alive and stay with their mother while they are fed on her milk.

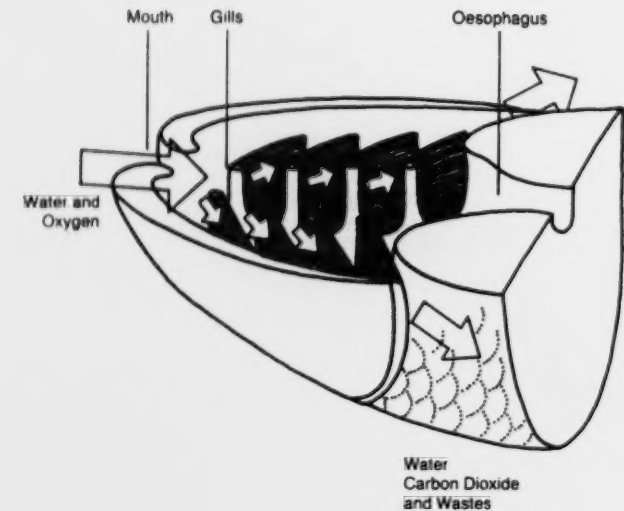
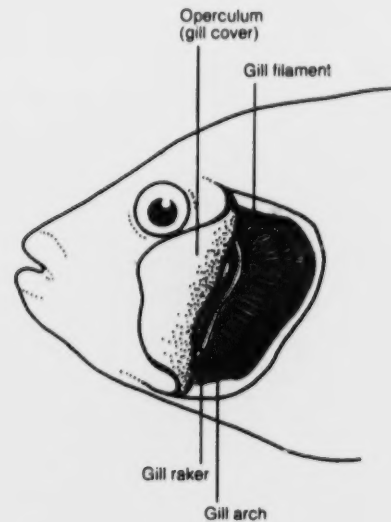
The blue whale, the largest animal on earth, is a marine mammal. It can grow to some 30 metres long. It can grow to this extraordinary size largely because the ocean water supports its weight. Other marine mammals are the smaller whales, dolphins, porpoises, dugongs (sea cow), seals, walrus and sea otters. All marine mammals must breathe air into the lungs as humans do and for this reason they must stay within reach of the surface of the ocean.



How Does a Fish Breathe?

As a place to live, water presents problems which are very different from those on land. For example, how do animals 'breathe' underwater? All animals require **oxygen**. In a fish the **gills** serve the same function as the lungs of air breathing creatures, that is they take in oxygen from the surroundings.

If you looked at a gill under a microscope, you would see rows of tiny, red 'feathers'. These structures, called **gill filaments**, are filled with blood. When a fish gulps in water through its mouth, water flows over the gill filaments and oxygen passes directly into the blood. Carbon dioxide and other waste materials pass out of the blood into the sea.



2.3 Benthos — The Bottom Dwellers

Several kinds of animals live in or on the sea floor.

2.3.1 Invertebrates — the 'Creepers' and 'Crawlers'

Most of the benthos are **invertebrates**, that is animals without **backbones**. Invertebrates are often described as the 'creepers' and 'crawlers' of the ocean for reasons that will become obvious as you read through this section. There are well over 1 200 000 species of invertebrates on earth. Some sea invertebrates look more like plants than animals; for example, the sponges and the sea anemones.

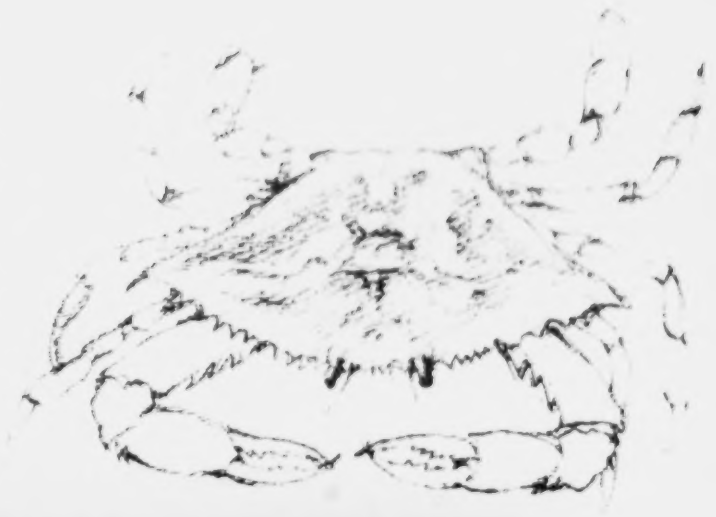
Shell covered invertebrates are called **molluscs**. They have either a single shell like the snail or two shells like oysters, clams and scallops. They burrow in the sand of the ocean bottom or creep around very slowly. A third group of molluscs have a hidden

internal shell and are mainly nektonic (squid, octopus).

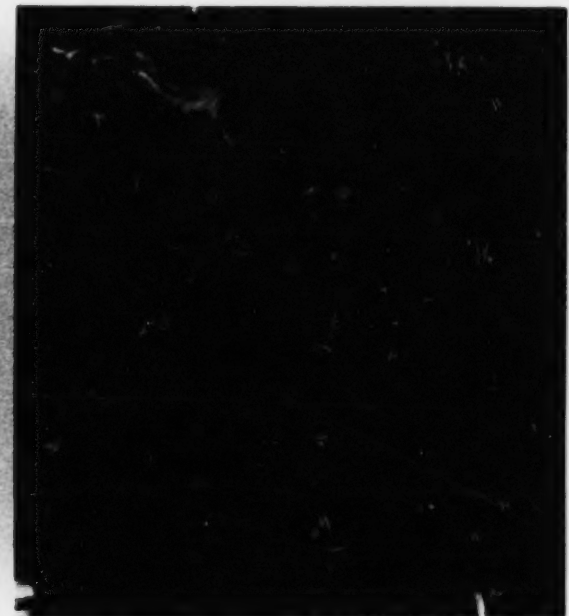
Arthropods are also common amongst invertebrate benthos. This group includes lobsters, crabs and shrimps. They are characterised by their tight-fitting body shell, by a segmented body, and a habit of shedding their shell periodically. Like fish, molluscs and crustaceans also take in oxygen through gills.

The benthic invertebrates have many different ways of moving about. Most molluscs 'walk' by means of a fleshy foot but scallops and octopuses can jet forward by squirting water backwards. Starfish and sea urchins progress on hundreds of tiny so-called 'tube feet'. The octopus and lobster find their food by moving about the sea floor. Other invertebrates drift in the open sea, like jellyfish.

Not all benthic creatures move. Sponges and sea anemones spend all or most of their lives attached to the sea bed.



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Gyotaku — Japanese Fish Printing*

History

'Gyotaku' means fish rubbing (gyo = fish, taku = rubbing). Fish printing originated in Japan or China in the early 1800s. (Plants have been printed in Europe since the 1400s.) In Japan, *gyotaku* is practised by sportsmen to preserve records of their catches. (A fish print never lies, but fishermen do!) In the United States, it has been practised as an art form for about 25 years.

Practising the art of *gyotaku* (pronounce gyo like your) is a good way to gain appreciation of the beauty and great variety of marine organisms. You can also use this technique for making prints of shells, rocks, flowers, and other objects of nature.

Materials

1. Obtain a **very fresh fish**. If you catch a fish yourself, keep it cold and try to print it within 24 hours.

Otherwise freeze the fish; it will print well when thawed. Be sure that the fish's fins or body are not severely damaged. You can gut the fish if you want to and then fill the body cavity with paper towels.

If you buy the fish at a market, select one with bright red gills, clear eyes, and a fresh smell. Look for fish with large rough scales, spines, reasonable size (6 to 18 inches), and a flat shape. Such fish as rockfish, flouders, bass, dories and perch are good beginning choices.

2. Thick water-based inks are best for beginning. Traditionally, the Japanese have always ground sticks of carbon-based sumi ink. Water-based linoleum block printing ink is another excellent ink, and it is easy to use. Black is a good color to work with, but you may want to try other dark colors such as brown, red, green, or blue.

3. You will need several brushes, ranging from size 00 for painting in the eyes to one inch for applying ink to the fish. The larger brushes should be fairly stiff because you want to get a very thin coat of the thick block printing ink on the fish.

4. Moisture-tolerant paper is used for printing. For the beginner, newsprint and sumi-e painting and sketch paper are recommended. Handmade oriental papers ('rice' paper) will give the best results, as you gain experience.

5. You will also need:
newspaper
plastic modelling clay
straight pins



*Adapted from *Gyotaku — Japanese Fish Printing*, Division of Agricultural Sciences, University of California, Leaflet no. 2548

Ask your teacher about the process of making a print.

2.4 Seabirds

How many different kinds of seabird are there?

Of the 8000 or so species of birds known to exist just over 200 can be considered seabirds.

What is the difference between a seabird and a landbird?

The main difference is that the seabird feeds on sea creatures, even though it makes its nest on land. Often these nests are made on cliffs and craggy islands which humans find almost inaccessible. Some seabirds, like seagulls, stay fairly close to shore. Others, like albatrosses, fly long distances across the oceans and spend a long time out of all contact with land.

Doesn't the albatross find this tiring?

No. The albatross makes use of the ocean winds to glide huge distances. By gliding on the wind it can greatly reduce the amount of energy it needs to stay airborne. This is one of the reasons why you will not find seabirds in parts of the ocean where there is no wind, like for example, the Sargasso Sea.

But the wind is important to seabirds for another reason, since it is the wind that creates the strong water currents that bring mineral salts up to surface waters. If there are no nutrient salts available, the tiny plants of the plankton cannot live. If there is no plankton there will be no food for the fish and other larger creatures on which the seabirds feed. Bearing this in mind, where would you expect to find the

greatest concentrations of seabirds?

Seabirds vary considerably in the degree to which they have adapted to a sea environment. Some birds, like seagulls, are equally at home on the land or open ocean. In contrast, penguins are highly adapted to a marine life. They lost their power of flight millions of years ago and their wings became modified into powerful flippers to propel them underwater.

Most sea birds have oily feathers so that they do not become water-logged when they are in the water. The oil creates a resistant surface and prevents too much water from being absorbed into the feathers. The osprey and shag are an exception to the 'oily feather' rule — they become waterlogged quite quickly when diving for fish, and often you can see only a neck or head when they are 'paddling' across the water. Or maybe you have seen them holding their wings out to dry.

Not all marine birds can fly. The penguin for example, can only swim and walk. Some birds, like flamingoes, have long thin legs which makes it possible for them to wade easily in both salt and freshwater lagoons.

Many marine birds, such as the cormorant, have webbed feet: the webbing helps them to paddle when they are on the water. You will see why if you experiment by opening all your fingers and running your hand through a basin of water. Then close your fingers and perform the same movement. What is the difference?

Some seabirds are migratory and travel vast distances across the ocean. One of these is the Short-tailed Shearwater (commonly known as the muttonbird). The muttonbird nests on the islands of Bass Strait in southern Australia. In May of each year it begins its 32 000 km flight around the Pacific, passing the East Indies and Japan, across the Bering Sea, down the West Coast of North America and back across to Australia, returning in September to its nest.

These lengthy migrations are not as tiring as they might seem because the muttonbirds use the prevailing winds to assist their flight.



Albatross



14 42

The pelican is one of the most familiar of all seabirds. It is famous for its throat pouch which is used as a dip-net for catching fish and also as a container for storing food.

There are eight species of pelican but only one, the brown pelican, is a seabird. The others live in freshwater lakes, marshes and estuaries.

The brown pelican is the smallest pelican and is found from the Gulf Coast to Venezuela on the Atlantic seaboard of America and from California to Chile, on the Pacific side.

Brown pelicans rarely go far from shore. They catch their fish by diving vertically. The pelican eats nearly 2 kg of fish a day. In United States waters its survival is threatened by the accumulation of pesticides in its body. The pesticides are present in polluted waters and are passed along the food chain.



43

Telling Birds Apart

How good are you at identifying different birds?

A pelican is a sea bird.

An egret is a wading bird.

An emu is a land bird.

Each one is large and you should be able to tell it from the others.

Below are characteristics of all three birds.

long neck
snake-like neck
long neck

long bill
long bill
short bill

large body
large body
large body

brownish drooping feathers
white feathers
black and white feathers

toes
long-toes/claws
webbed feet

long legs
long legs
short legs

Match these descriptions to the right bird, and work out which is the pelican, the emu and the egret.



More About the Pelican — What We Can Learn From What Others Choose to Communicate

If you can't go to where the pelicans live, how can you find out more about them? You will have to depend on what you can read, or see drawn or photographed. In other words, you may have to rely on other people's observations and the ways in which they communicate them to us.

Here we are going to look at a number of drawings and see what we can learn. We will be looking at three main types of drawings —

- objective
- stylised
- expressive



45

An example of each is given below. Use these as a guide to identify the types of drawings shown on the next two pages.

Discuss your groupings with others in the class. Under separate headings, write a paragraph on what you learnt about pelicans, their life and habits, from (a) the objective drawing (b) the stylised drawing and (c) the expressive drawing.

When you have finished this, add another paragraph saying what you think are the main aims and uses of each type of drawing.



An **objective drawing** is:
natural in appearance
about what something looks like
as realistic as possible.

An objective drawing can be modelled with light and shade.



A **stylised drawing** is when the natural features have been:
simplified
replaced
modified
omitted
emphasized
changed.

A stylised drawing uses mainly lines and flat shapes — no shading.

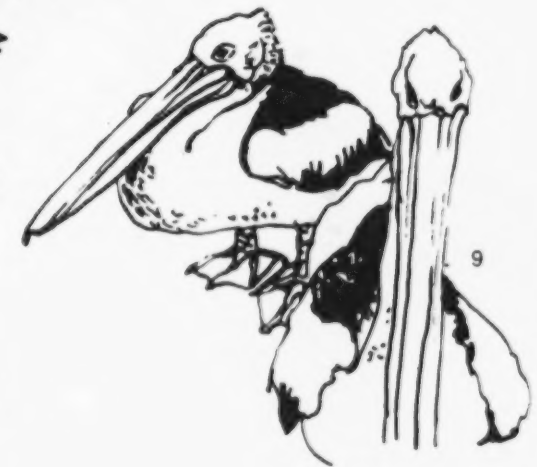
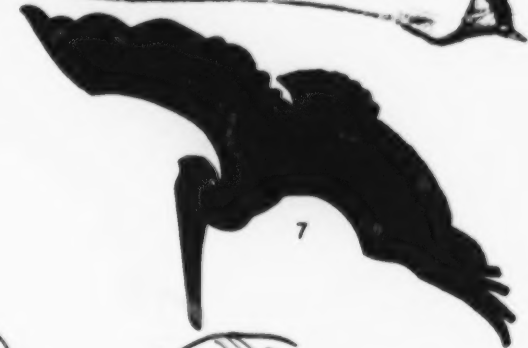
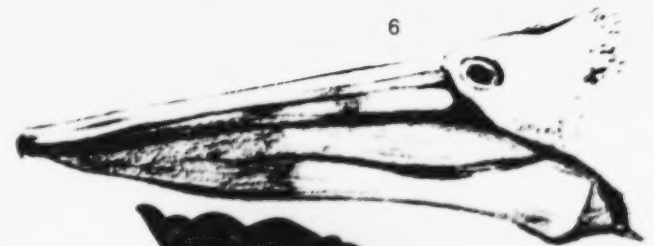


An **expressive drawing** is:
interpretive
personal
individual
unique.

46

Pelicans Galore

Which of these drawings are:
objective?
stylised?
expressive?





10



12



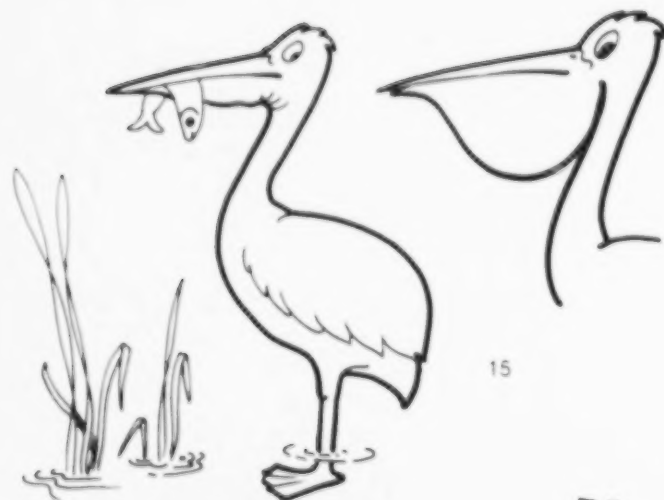
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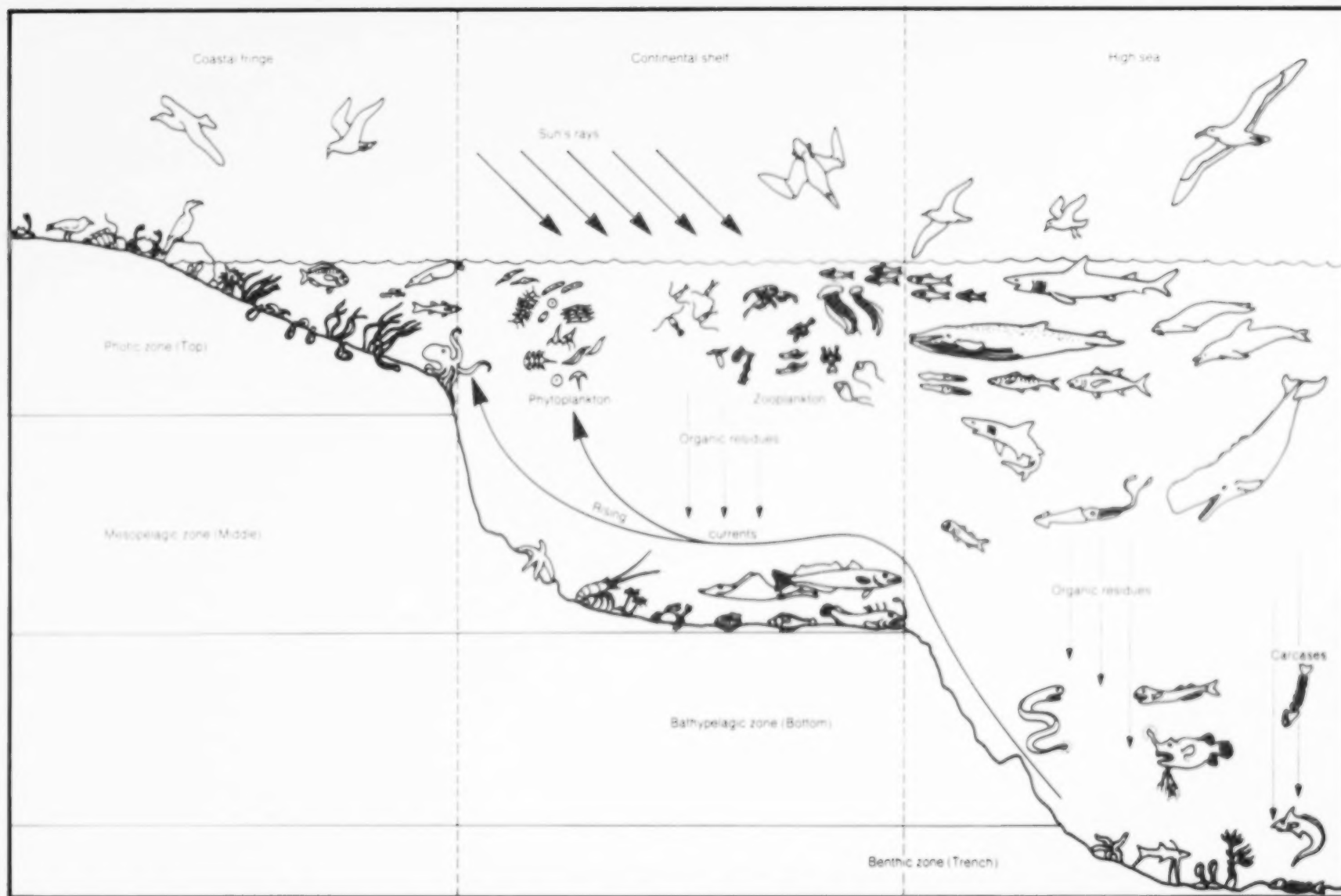
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The surface zones, illuminated by the sun, are inhabited by a multitude of species. The intermediate zones are populated by many organisms which depend for food on debris drifting down from above. In the abyss there is an

accumulation of mineral elements, which because of rising currents, are borne up towards the surface. These are vital for the development of algae (phytoplankton and seaweed).

Note that this diagram is a simplification.

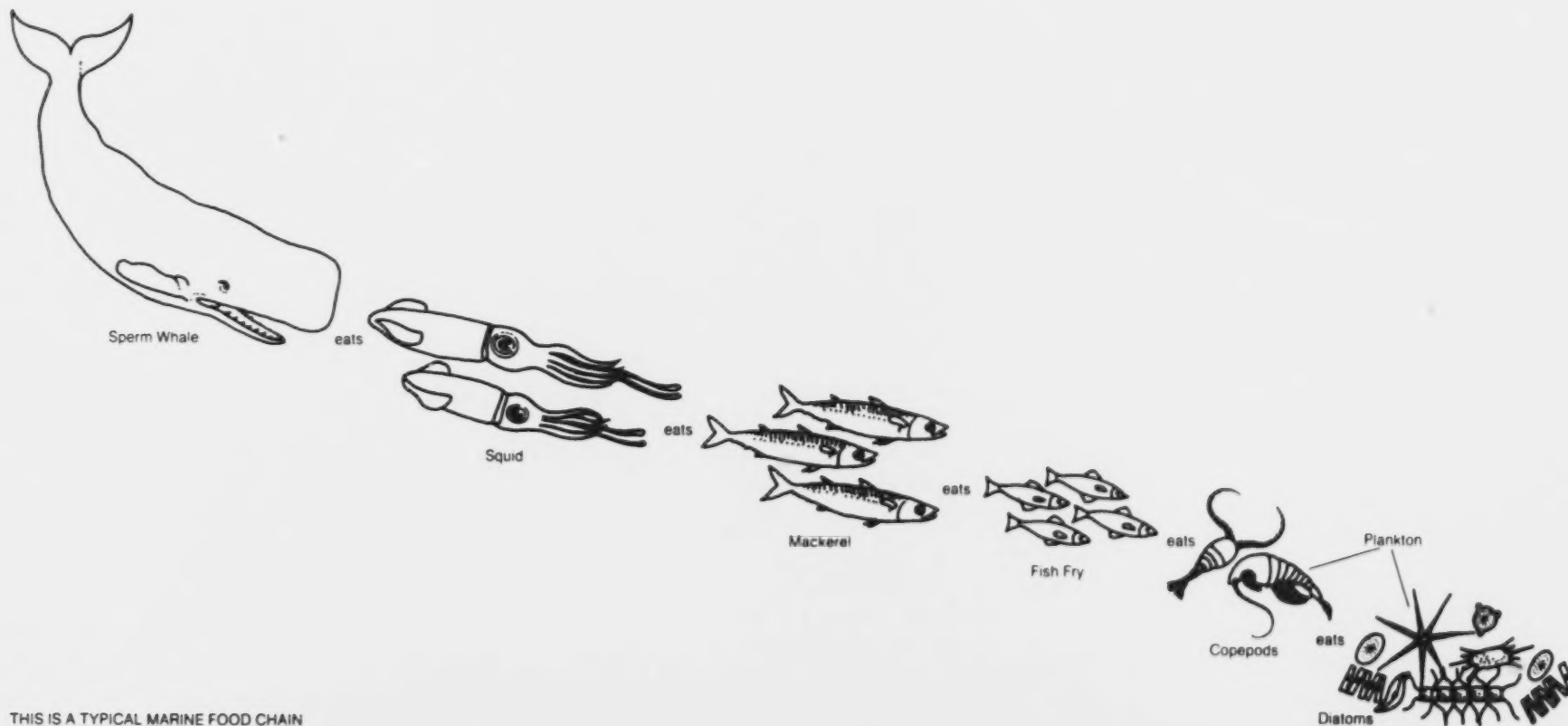
The sun shines on the surface of all the ocean and plankton is present not only on the continental shelf; tuna, whales and seals are also found closer to shore.

2.5 The Flow of Food

2.5.1 The Food Chain

All sea creatures are **interdependent**. Larger fish eat the smaller ones and small fish eat the oceanic plant life, the phytoplankton. This is called the **food chain**.

Phytoplankton are the basic link in the food chain. As we saw in section 2.1.1 on page 14, marine plants produce their own food through photosynthesis. They are the **producers** of the ocean. If there were no plant life in the ocean there could be no animal life. Ocean animals are the **consumers** of the ocean.



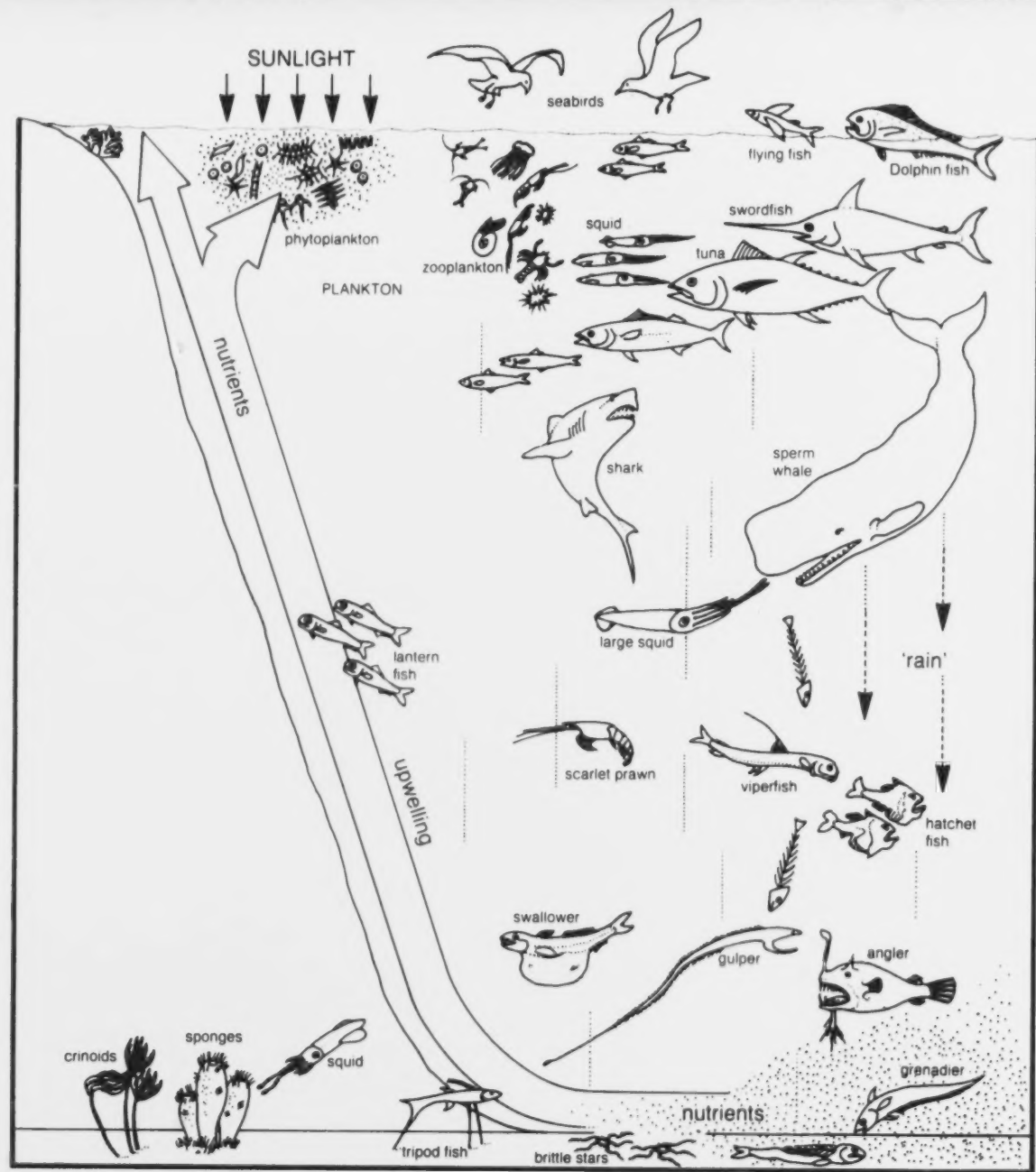
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2.5.2 The Food Web

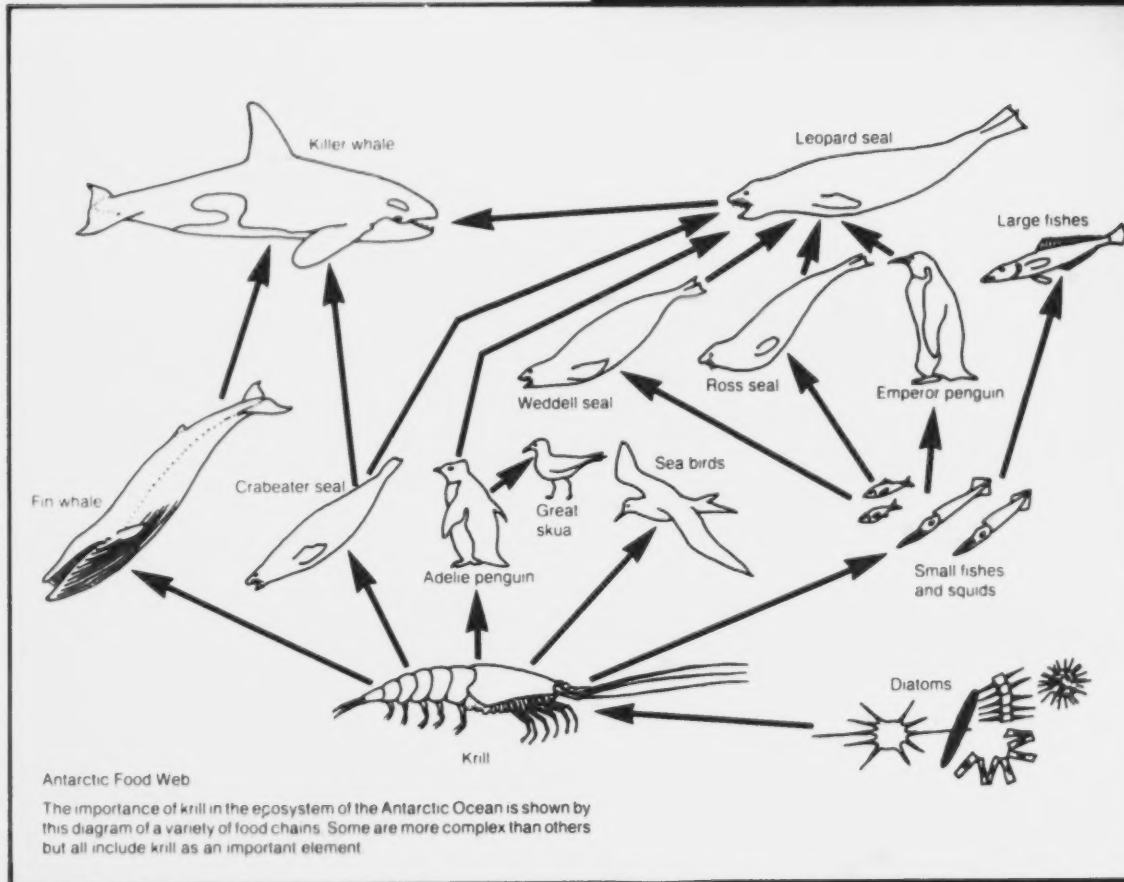
There are many food chains in the ocean and they interweave to form a complicated **food web**. The beginning of the web is in the sunlight zone of the ocean. Here, microscopic phytoplankton use energy from the sun to grow. The phytoplankton then serve as food for other microscopic animals which in turn become food for larger animals.

Far below, away from all the activity of the surface that we can see, are the animals of the darkest depths. These animals feed on the steady 'rain' of food that falls to the ocean floor. What is not eaten is **decomposed**, or broken down by **bacteria**, into the **minerals** of the sea floor. These minerals remain there, unused, until they are brought up to the surface as **nutrients** or fertiliser for phytoplankton. The nutrient minerals are brought up to the surface by rising deep-sea currents. This action is called **upwelling**.



The diagram **Marine Food Web** on page 30 gives an indication of the general principles at work in the function of a food web and the **re-cycling of energy**.

If you look at the diagram below, **Antarctic Food Web**, you will get a clearer picture of how the various food chains in a particular eco-system (in this case, the Antarctic Ocean) inter-relate.



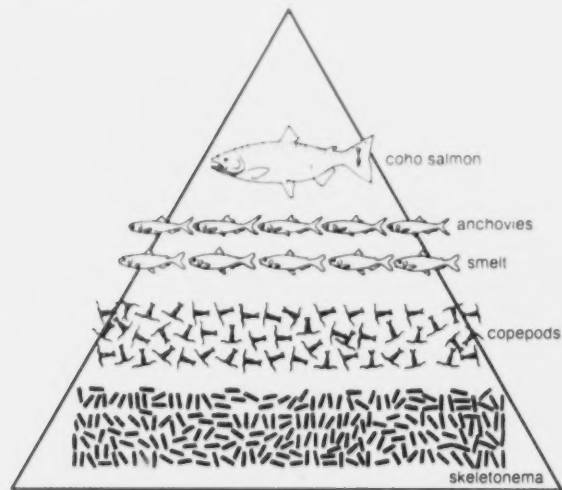
These food web elements are not all drawn to the same scale. See if you can find out the relative sizes to which they grow.

2.5.3 The Food Pyramid

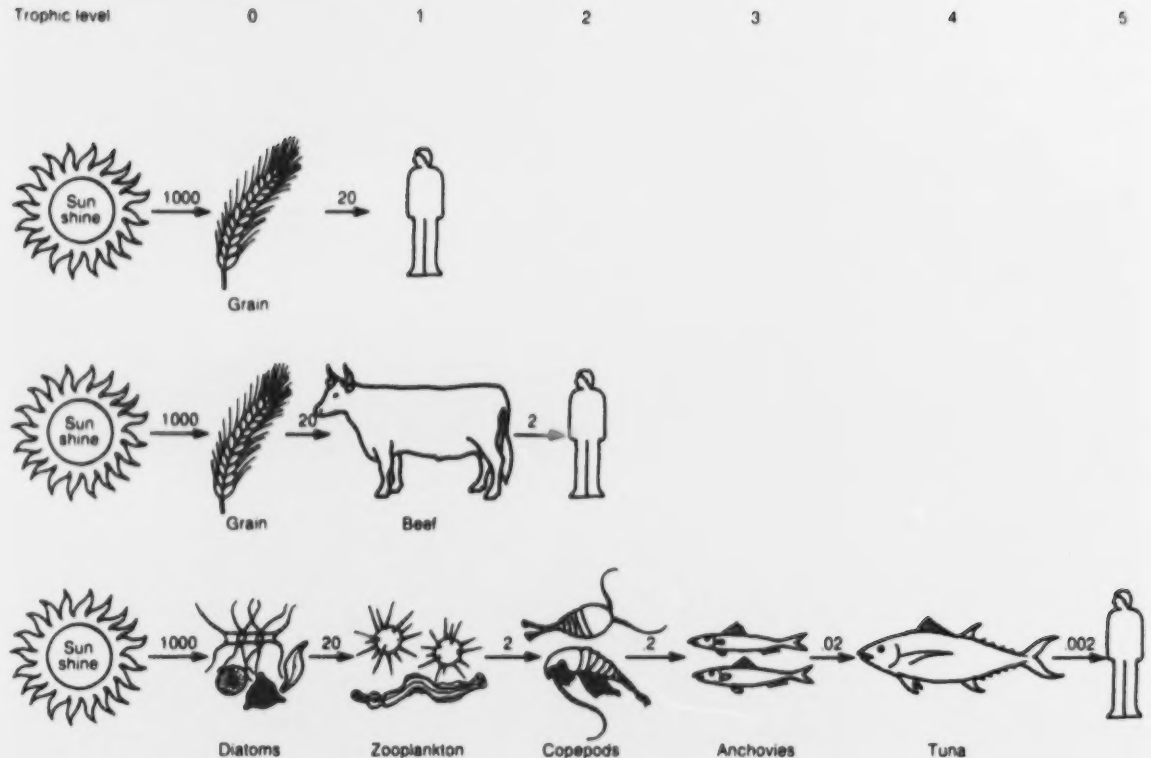
One of the most striking features of a food chain is the way in which the larger fish feed on the smaller. Vast numbers of tiny plants and animals help to support just one predator. This particular aspect of the food chain can be represented as a **food pyramid**.

The diagram below shows the food pyramid that supports a Coho salmon. Coho salmon are found on the Pacific Coast of northwest U.S.A. The diagram is only a **representation** of the concept of the Coho salmon food pyramid. In actual fact, **millions** of phytoplankton are needed to sustain **thousands** of zooplankton. These zooplankton in turn feed the **ten** fish in the next layer which finally nourish **one** Coho salmon.

Food Pyramid



The relationships between each level of the pyramid in terms of **weight** are not as simple. In some food pyramids, for example in a forest, the weight of plants on the base would be about 10 times that of the animals which feed on them. In turn, the weight of these plant-eaters is about 10 times that of carnivorous animals which feed on them. In the sea



however, the weight of phytoplankton may often be less than that of the zooplankton which feed on them. This apparently impossible situation is explained by the fact that phytoplankton grow and breed much faster than the zooplankton. Therefore, over a period of time, a larger weight of phytoplankton than of zooplankton is formed in the ocean.

The Ocean as a Food Resource for Man

Scientists call each level of the food pyramid a **trophic level** — meaning, a 'level of nourishment'. The lower the trophic level we harvest from, the more

efficient is our use of the sun's energy. If you study the diagram above you will see that the amount of food produced at the first trophic level is about the same (20 calories per 1000 calories of the sun's energy) for each food source (grain, beef and fish). Can you explain then, why it is that 98% of our food production comes from the land, and only 2% from our fisheries?

efficient is our use of the sun's energy. If you study the diagram above you will see that the amount of food produced at the first trophic level is about the same (20 calories per 1000 calories of the sun's energy) for each food source (grain, beef and fish). Can you explain then, why it is that 98% of our food production comes from the land, and only 2% from our fisheries?



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00 62

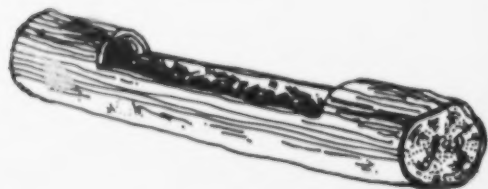
3.0 Exploring the Surface of the Ocean

The oceans have been highways for centuries. Until the development of commercial air travel they provided the only link between continents. They still provide the cheapest form of intercontinental transport.

The first boat was probably a log rolling from the bank into the water. By sitting astride it, a man could propel it forward.

Early inventors hollowed out suitable logs with stone axes and fire.

They used tree branches to move the boat, eventually discovering that it was better to shape the branches into paddles.



above: Double canoe from the Hawaiian Islands, 1778.
right: Egyptian model boat with mast and oar, 2000 BC.

Sails were hoisted to take advantage of the wind. Lightness was achieved by stretching skin or bark over a framework.

Then there was the raft. Rafts are still made in more or less the same way, using bundles of reeds, logs, grasses and other material. From the raft, many peoples progressed to making boats with built-up hulls, sometimes using a framework covered by skins or bark.

Our earliest record of ships are images painted on vases and cut in stone. From these we know that the Egyptians of at least 3000 BC had boats with mast and sail.



The Phoenicians, Ancient Greeks and Romans built galleys, open ships propelled by oars as well as sail. Steering was done with an oar lashed near the stern.



Roman trireme, 260 BC.

At this stage in history Chinese navigation was more advanced than that of the Europeans. They had known about the axial rudder and the compass since about the first century AD and they also produced the first printed maps. The rudder allowed for better steering. The compass enabled navigation out of sight of land and without fear of overcast skies hiding the stars. The multi-masted ship was also a Chinese idea brought to the West at the time of Marco Polo in the thirteenth century.

When these discoveries reached Europe they had a great impact on European seafaring. Towards the end of the fourteenth century Henry the Navigator, a Portuguese prince, initiated a European age of exploration. In 1486 Diaz rounded the Cape of Good Hope. In 1492 Columbus discovered the New World. In 1498 de Gama sailed around the Cape of Good Hope to India and in 1513 Balboa discovered the Pacific Ocean.



During this period ships became bigger and more complex in design, culminating in the sixteenth century galleons. From then until the late nineteenth century ships increased in size and number of sails but did not alter much in basic principle of design until the coming of the steamship.

The steam-engine of James Watt provided a new source of power more dependable than wind. In 1790 John Fitch was generating a steamboat service on the Delaware river in the United States.

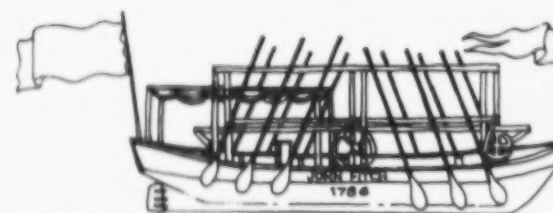
In 1838 the British steamer *Sirius* was the first ship to cross the Atlantic under continuous steam power.

left:

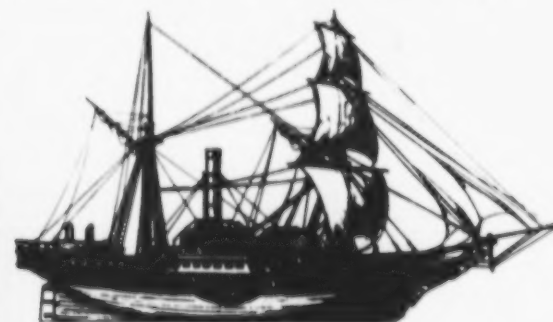
A fourteenth century English single masted vessel

below:

The *Ark Royal* — Flagship of Queen Elizabeth 1, late sixteenth century



John Fitch's steamboat — the engine worked twelve vertical oars.



Sirius — Steamship with paddle wheels



Great Britain — First iron-hull transatlantic liner with propeller propulsion. Length 98.72 m (324 ft).

The giant *Great Britain* was the first propeller-driven ship to cross the Atlantic in 1843. It showed that iron ships could carry more cargo more safely than wooden ones. Around this time the great fleets of passenger lines came into operation.

By the end of the nineteenth century steel had replaced iron as the standard material for hulls. Steam and diesel engines became more reliable and sails were abandoned altogether.

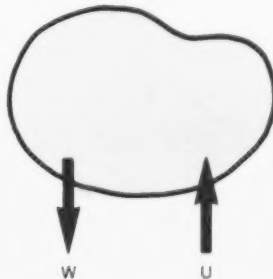
3.1 Staying Afloat

Water has an important property called **buoyancy**. It is this characteristic that causes things to float and hence enables people to explore and use the sea.

If you place an object in water it displaces or pushes aside some of the water. You may also have noticed that objects seem to weigh less in water than in air. Over 200 years ago the Greek mathematician Archimedes made similar observations.

If you fill a glass brimful of water and then carefully drop a pebble into it you will find that some water overflows. If you collect this water in a saucer you can weigh it. Tie the pebble to a spring balance by thin, light cotton and compare its weight in air with its apparent weight in water. The weight of the water displaced is equal to the apparent loss of weight of the pebble. This is an example of the workings of **Archimedes' Principle**: Any object placed in a liquid is pushed upwards by a force that is equal to the weight of the liquid that the object displaces.

Now if an object displaces a volume of water that is equal to or greater than its own weight, then the upthrust of the object will counteract the weight and the object will float.

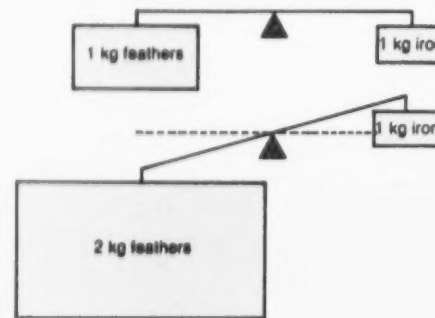


If $U \geq W$ (upthrust $\geq$ weight) then the object floats. If $U \leq W$ then the object sinks.

A tiny, heavy object such as a pebble displaces a small amount of water. It sinks because it is heavier than the water it displaces. A block of dry wood, a piece of cork or a lump of foam rubber will float on

water. They do so because they weigh much less than their own volume of water. Even when they are only partly immersed in the water the upthrust is enough to buoy them up. What is important here then, is not the weight of the object in water but the relationship between its weight and size. We call this relationship **density**. **Density** determines whether or not an object floats. If it is less than that of water it floats, if it is greater than that of water it sinks.

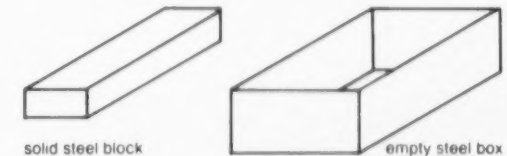
We have to use the words **density** and **heavy** carefully. When we talk about density we are referring to the quantity of matter in a given space. If there are two identical bags, one full of feathers and one full of iron filings, which would you prefer to lift up? Clearly the one filled with iron filings is heavier. While it is true to say that 'iron is heavier than feathers', obviously one kilogram of iron weighs the same as one kilogram of feathers. It is their density that is important. The kilogram of iron takes up less space.



3.1.1 Why a Steel Ship Floats

An object floats when its weight is less than the weight of an equal volume of water. When we see a piece of steel we know that it is a dense substance. In fact, volume for volume, steel is about eight times heavier than water, so that we expect the steel will sink when it is placed in water and it does if it is in the form of a solid block.

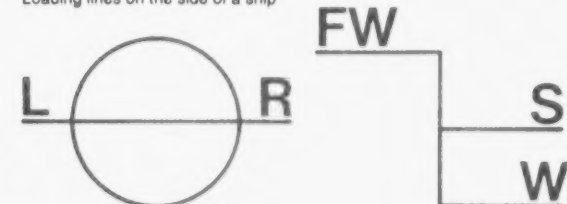
Now suppose the steel is flattened out into thin sheets and that the sheets are joined together to make a completely enclosed metal box with air inside. It will float! The average density of the whole box is much less than the density of solid steel and even less than that of water.



A steel ship is just a specially shaped metal box! You can put a lot of cargo in the ship and still its **average density** will remain less than that of water and it will still float. Thus, large ships made of steel can carry heavy cargoes. When a ship is **overloaded** its density becomes dangerously high and it will sink too deeply into the water. It may seem stable enough in the calm waters of the port but would be in danger if caught in a storm at sea. When a ship is registered the **Plimsoll line** is marked on the hull to indicate how much weight can be safely loaded. This system of marking is named after Samuel Plimsoll, a British politician and social reformer, who introduced regulations to ensure that seamen did not have to go to sea in dangerously overloaded ships.

Can you explain why a ship rises when it moves from fresh water to sea water?

Loading lines on the side of a ship



FW = Fresh water
W = Winter
S = Summer
LR = Lloyd's Register

3.1.2 Exploring the Pacific Ocean. The Early Navigators

The first sailors of the Pacific were probably the Polynesians. Long before men like Columbus dared to sail beyond sight of land, the ancestors of the South Sea Islanders were settling on distant shores. They came from Asia in dugout canoes lashed together and rigged with sails. Their achievement is all the more remarkable when we consider that the only building tools they had were made of stone.

The Pacific Islanders were, and are, among the world's most skilful navigators. Centuries before the development of modern aids to navigation, such as the compass and radar, the islanders were able to travel with remarkable accuracy for several thousand kilometres in their relatively small sailing canoes.

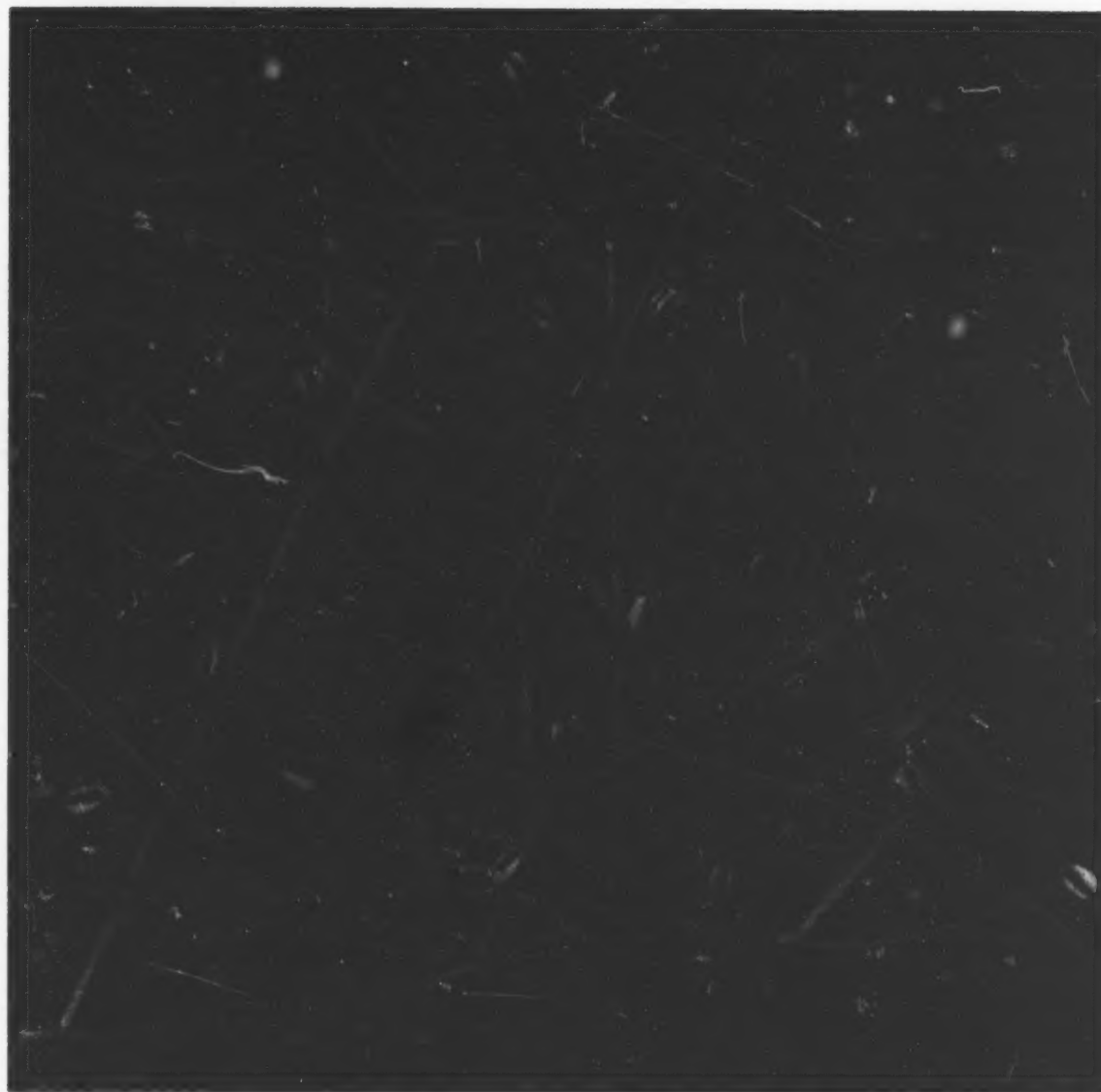
The islanders developed a method of navigation — finding their way — which depended on **observation** of things around them:

- the stars and the sun
- ocean currents
- winds
- the presence of homing sea birds
- cloud formations over land
- the colour of the sea
- the kinds of fish and seaweed caught on hooks
- and
- ocean waves being bent by the presence of land.

In some places this information was woven into maps of reeds, sticks and shells and preserved without the need of a written language.

Before Europeans had ever set eyes on the Pacific Ocean the islanders had developed a flourishing trade between islands many hundreds of kilometres apart.

The extract on page 38 conveys some idea of the difficulties and discomfort involved in these voyages.



The Micronesians were skilled sailors and navigators. For frequent, two-way journeys, they made navigation charts like this, with small stones or shells indicating islands and sticks to show the routes and ocean currents.

Hokule'a Follows the Stars to Tahiti

In the early 1970s a group of people from Hawaii decided to retrace the steps of an early trip from Tahiti to Hawaii. For the trip they built the boat, the *Hokule'a**, in traditional style. Below is a report by David Lewis on part of their trip.

It was nearing three o'clock in the afternoon, although none of us could be certain of the time. We had already surrendered our watches, for they would be potentially useful instruments in navigating the 4800 empty kilometres that lay ahead.

On the shore at Honolua Bay — a tiny, deep, and lovely cove on the northwest coast of Maui — a kahuna, or Hawaiian priest, touched each of us in turn and spoke of the final blessing: 'You belong no more to the land; you are now dedicated to the sea

....

We went down to stand knee-deep in the water, whence we were ferried out to *Hokule'a* in a specially consecrated outrigger canoe. Henceforth, until we reached our destination, we must not go ashore again.

And so 17 men and the poi dog, Hoku, left Hawaii for Tahiti on May 1, 1976, some 800 years after the last great wa'a kaulua (double canoe) had made the voyage.

The 20 metre, twin-hulled *Hokule'a* carried claw-shaped cotton sails on her two masts. She was built largely of modern materials, but her lines were ancient — reconstructed from sketches by Captain Cook and others, so that her performance paralleled that of Polynesian voyaging canoes of long ago.

Our purpose in retracing this ancient sea route in a re-creation of a 12th century craft was to gain insight into how such voyages might have been made many centuries ago.

Above all, we would be testing the accuracy of long-distance navigation entirely without instruments, as well as the canoe's ability to deal with head winds and currents. If successful, we would be demonstrating that ancient Polynesians were, indeed, able to sail purposefully and repeatedly over vast areas.

**Hokule'a* means 'Star of Gladness' in Hawaiian.



Hoku Li'i Li'i (Tiny Little Star), our little golden poi dog, was born in the Honolulu Zoo and represented an attempt to breed back to the original Polynesian barkless vegetarian dog used for food. The zoo had also bred razor-backed pigs and Polynesian chickens, but at the last moment the director decided they were ill-prepared for the

voyage and declined to let them sail with us. So Maxwell, a white and very domestic pig (he was disadvantaged on both counts, we were to discover), and a cock and hen were hurriedly purchased. The dog, the pig and the Indonesian chicken had been the animals the Polynesians brought with them in their canoes, and one object

of the voyage was to learn how to feed and care for them.

There were plants, too, aboard *Hokule'a*: sprouting coconuts, breadfruit, sweet potatoes, sugar-cane roots, and a dozen other useful species that ancient Polynesian explorers had introduced into empty Pacific islands, including Hawaii. Our specimens were bundled in layers of damp moss swathed in tapa cloth and stowed in the hulls.

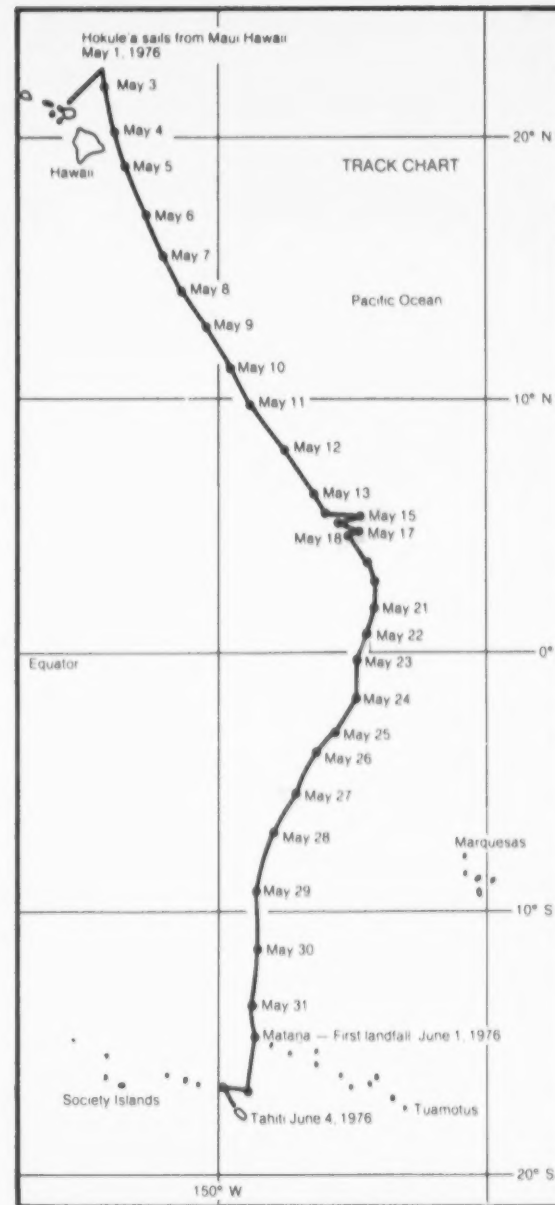
On the eve of our departure we had been purified in a sacred kava ceremony; until the taboo was lifted by our arrival in the Tahitian archipelago, wine and women would be forbidden. Then the navigator and sailing master, Mau Pailug of Satawal, one of the distant Caroline Islands of Micronesia, addressed the ship's company. We were a mixed group of Hawaiians (mostly expert watermen, surfers and paddlers) and haoles — non-Hawaiians. But only a handful of us, Pailug knew, were experienced offshore sailors.

'I wish to speak to the whole crew, how they should conduct themselves in the deep sea,' he said. 'Before we sail, we must throw away all things worrying us. On the ocean all the food, all the water, is under the control of the captain . . . everything the captain says to do, we follow. Only the captain tells us when to change course.'

'When we are on the ocean you cannot see any islands. Only the things we bring with us help us to survive. We act together. That is all I have to say. Remember, all of you, and we will see that place we are going to.'

Perhaps, in the weeks to come, his words might have been better heeded.

Volleys of spray swept the canoe's deck platform, and we soon found that neither the hale (the thatched shelters) nor the canvas spray covers fitted over the hulls offered much protection. That first night some of the crew laid plastic sheets or rubber storage bags over the slatted decking and rolled themselves in spare sails, others strung hammocks under the thatch. Hoku, the dog, was tucked into her specially made sleeping bag. The chickens seemed content in their coop, but Maxwell the white pig lay miserable and seasick in his



bamboo cage.

I was among those who chose to sleep in a puka, one of the two metre spaces between bulkheads in the hulls. I wore oilskins 'down below', however, for jets of water spurted constantly through insignificant openings in the canvas cover. I christened my puka the 'water bed' but I slept soundly there for the seawater was warm — in marked contrast to some I have known.

Pailug was, of course, the central figure in our navigation experiment. On his home island, Satawal, ocean voyaging in sailing canoes without instruments is still the way of life. Now 44, he is stocky and short; his nickname, 'Mau', means 'strong' in Satawalese.

His formal training began when he was six years old and ended at 18, when he was initiated as a fully qualified ppalu, or star-path navigator. He has since roamed far and wide through the central Carolines. In 1974 he navigated his 10 metre outrigger sailing canoe from his home island to Saipan in the Marianas and back, without chart or compass — a distance each way of about 805 kilometres.

Hokule'a's fireplace was a steel pan (the old voyagers had used a wood frame) lined with coral gravel. Over a fire of coconut husks Pailug cooked the first meal: sweet potatoes and bananas and sour fermented taro poi.

In the first few days out of Maui the trolling lines brought in three 13 kilogram mahimahi, or dorado. The crew grated coconut and squeezed out the milk, in which thin slices of fish were marinated to be eaten raw. They also sliced steaks from the fish to be boiled and served with sour poi. Both were delicious. To everyone's relief, Hoku thought so, too; she had now also developed a taste for coconut meat. She had found her sea legs, and walked the deck with the rolling gait of a veteran sailor.

Hokule'a's progress during the second week continued to be good, with daily runs of 190 to 210 kilometres.

Day after day we were visited by mid-ocean birds like petrels and shearwaters. But brown

boobies also followed us; one day we counted no fewer than 13. This was unprecedented in Pailug's experience as well as my own. Boobies are usually found no more than 80 kilometres from land, yet these were a good 1100 kilometres from the nearest shore, in the Line Islands to the west.

The trolling lines brought in an occasional fish — tuna, albacore, dorado — and two small flying fish came aboard by themselves, to Hoku's thorough enjoyment. Once a squid jetted onto the deck to become (sliced and marinated) a welcome *raw hors d'oeuvre*.

We entered the doldrums on May 13. Calms, variable light winds, and torrential rain squalls now became the order of the day. One shower alone yielded 60 litres of rainwater to refill some of our plastic jugs.

Between showers the sun blazed down out of a cloudless sky. All hands, including Hoku, took to the water. In one unscheduled swim, Clifford Ah Mow set out on his surfboard to rescue the plastic bag containing my notes that I had carelessly let slip. Laundry that usually trailed astern now dangled limply below the surface. On the other hand, washing ourselves — with buckets of seawater and household detergent — became more of a pleasure in the warm sunlight.

Hobbies like square knotting (macrame) and model building became general. *Hokule'a* continued to creep southward at an average of 65 kilometres a day. Frustrating as this was, it was clear that paddling would have gained us little or nothing.

Temperatures began to fray as days slipped slowly by. Under the most favorable of conditions, 17 men crammed aboard a 20-metre boat could scarcely avoid getting on one another's nerves. Buffalo Keaulana's laconic prayer before one meal summed up all our feelings: 'Thank you for the food. Give us some wind. Amen.'

I logged the crossing of the Equator at 1 a.m. on May 23.

We had covered, Pailug and I agreed, nearly 3200 kilometres; Tahiti lay 1600 kilometres south and a little west.

A school of porpoises surfaced and played alongside. Furious barking startled us. Hoku, hackles up, had found her voice and was loudly berating the intruders. Her initial reaction was much the same to a booby that sailed toward us, but as it glided nearer — and its true size became apparent — Hoku prudently turned and scampered into the hale.

Hoku's trials were as nothing compared to Maxwell's. Growing at the rate of about 500 grams a day, he outgrew his bamboo cage, a good portion of which he ate. Under the equatorial sun his white skin became badly burned. A piece of sail was draped protectively over the remains of his cage. To our distress, we found him lying on his side next morning, forlorn and coughing. He had eaten the sail!

We had no idea how to treat a pig with acute dyspepsia, and for several days had fears for



The Polynesian triangle of the Pacific (above) is the heart of the South Sea Islands civilization. Yet it has always been a source of mystery, for no one knows where the Polynesians' ancestors came from.

Maxwell's life. Eventually, however, his remarkable constitution came to his aid. He resumed his ravenous consumption of dried fish as if nothing had happened.

Toward evening on Monday, May 31, the familiar swell from the southeast abruptly cut off. It could mean only one thing: We had sailed into the shelter of Tuamotus lying to the southeast. Then Rodo Williams, the Tahitian navigator, pointed to a pair of soaring terns. 'You see *Italae*? We find land soon — this bird never fly more than 50 kilometres from land!'

That night the watch on deck, cautioned to keep a sharp lookout, stared intently into the darkness. About 3 a.m., June 1, a black line became visible on the port bow. It steadily grew denser and more solid — for certain, now, an island!

Houses appeared under the palms as we neared the land, and two boats emerged from the narrow pass through the reef. A dog swam vigorously out through the surf toward us while Hoku whined with excitement. Once we were inside the pass, islanders rushed out to manhandle *Hokule'a* and festoon us with leis. Despite our vow at the start that we would not set foot on land until we reached Tahiti, we stayed overnight at the hospitable atoll. Next morning we set out on the last 270 kilometres leg to Tahiti.

Excitement grew as we neared our goal. The following day a boat from Tahiti drew alongside, and its occupants tossed bottles of champagne and cans of beer aboard *Hokule'a*. After a month of close confinement at sea the tension had grown almost unbearable for one or two members of the crew. Grievances — real or fancied — were loudly aired, and one crewman swung several punches before reason finally prevailed.

But no one could sustain ruffled feelings in the warmth of our welcome when next morning *Hokule'a* sailed triumphantly into Papeete harbor. I think all Tahiti was there to greet us — the water swarming with canoes, the shores packed with people. None of us will ever forget the scene.

From David Lewis, *The Voyaging Stars: Secrets of the Pacific Island Navigators*, Collins, 1978

The Coming of the European — Magellan

In 1519 the Portuguese sailor, Ferdinand Magellan, sailed to the South Sea first sighted by Bilboa in 1513. Rejected by the Portuguese king, Magellan fitted out a fleet with the support of the Spanish who hoped to find a new trader route by which Spain could exploit the spice trade of the Indies.

Magellan's expedition was the first to cross the vast Pacific Ocean. It did so under severe hardship because Magellan believed the Pacific to be only 600 miles wide, not 11 000. (About 1000 not 17 700 km.)

Magellan and many of his crew died on the voyage but the remainder of his men completed it and were the first to circumnavigate the world. Although their voyage was an epic one it did not greatly add to our knowledge of the land forms in the Pacific Ocean.



Magellan's voyage around the world



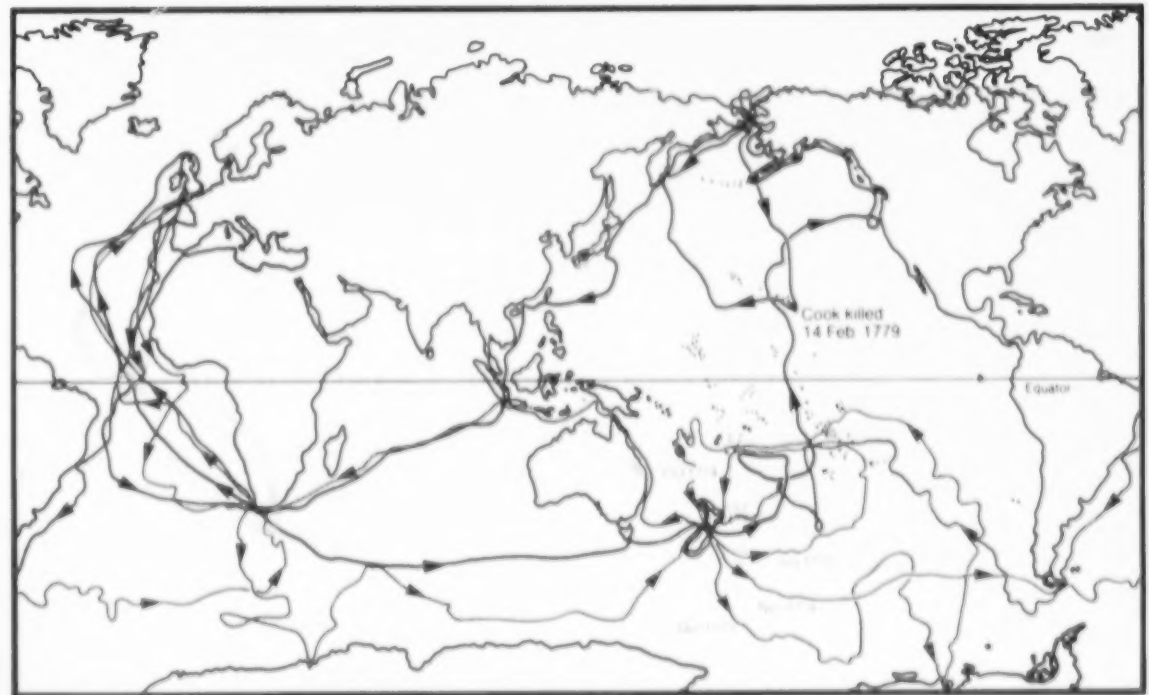
Astrolabe

Cook

The Englishman, James Cook, was the greatest of the European explorers of the Pacific Ocean.

Cook set out on his first voyage in 1768, 250 years after Magellan. He made three voyages to the Pacific in eleven years. In that time he mapped and charted most of the Pacific as we know it today. If you look at the map you will get some idea of just how great Cook's achievement was.

James Cook



— First voyage — 1768-71
 - - - Second voyage — 1772-75
 . . . Third voyage — 1776-79



Sextant

3.1.3 Language from the Sea

As everyone knows sailors have always had their own slang, a great range of expressions based on the work they do on board ships and their relationship to the sea itself. How many of us realise that many of these expressions have passed into the everyday language and are used by those of us who have never been to sea.

Below you will find examples of sea expressions that have entered into the common language of us all.

Aboveboard: Above the water line. In shore speech it means frank, open, fair dealing.

To make a clean sweep: Refers to the sea breaking over the rail, washing overboard all moveable objects on deck. The phrase in shore speech means to get rid of everything; to start afresh.

Doldrums: A belt of calm, rainy weather at the equator, separating the trades. Used on land to mean low spirits, boredom, 'the dumps'.

Hard up: With the rudder over as far as it will go, so that nothing further can be done. We use it figuratively to mean poor.

Sails: Several expressions originate in the process of handling sails. To trim one's sails according to the wind is to be guided by expediency. To take the wind out of one's sails is to sail windward of another vessel and thereby cut off the wind; figuratively to frustrate or forestall.

To spin a yarn: In making spun yarn from untwisted yarns of rope, it took two sailors to operate a small winch. They worked in a sheltered spot, enlivening their task with conversation. Hence to spin a yarn is to tell a story, usually a 'tall' one.

There are many other expressions that have made the journey from sea to shore. See if you can trace the origin and meaning of the following:— aback; aloof; batten down; bear down; bearing; bearings; cast about; happy as a clam; derelict; dungarees; graveyard shift; loanshark; to pour oil on troubled waters; to go to pieces; scuttle; scuttle butt; so-long; staunch; tack.

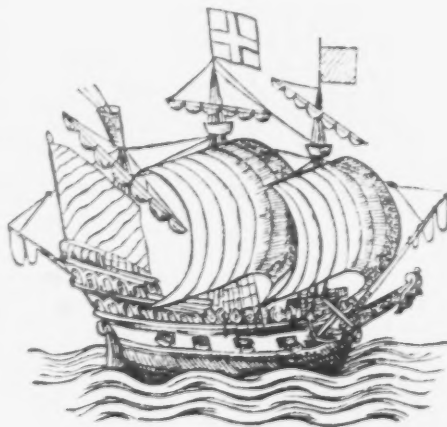
Reference: JoAnne Carver Colcord, *Sea Language Comes Ashore*, Cornell Maritime Press, New York, 1945.

Seamen's Proverbs

Seagull, seagull, stay on the strand
We'll ne'er have good
Weather with thee on the land.

The evening red and morning red,
Are sure signs of a fine day;
But the evening grey and morning red,
Makes the sailor shake his head.

When rain comes before the wind
Halyards, sheets and braces mind,
But when the wind comes before the rain,
Soon you may sail again.



3.2 Waves, Currents and Tides

The movements of the sea have inspired poets and painters of many ages. The coast has always been a special place, long associated with rest and joy and peace of mind. Staring at the sea and the movement of waves is considered by many cultures to be a desirable form of meditation. But the coast can also be a place of death and destruction, especially for people living in volcanic areas where 'tidal waves' are always a possibility.

For many of us it is the **movement** of the sea (described by poets as the 'mood' of the sea) that holds a special fascination. For those whose lives and livelihood depend on the ocean, fishermen and sailors especially, the movements of the sea are not just a source of wonder but the basis of their survival. They must have a detailed and scientific knowledge of the trends and recurring patterns of ocean movement so that they can **predict** oceanic behaviour and plan their work accordingly. These people must know everything there is to know about waves, currents and tides.

3.2.1 Waves

The energy that makes waves comes from

1. Winds that blow across the ocean
2. Storms out at sea and
3. Movements of the sea floor

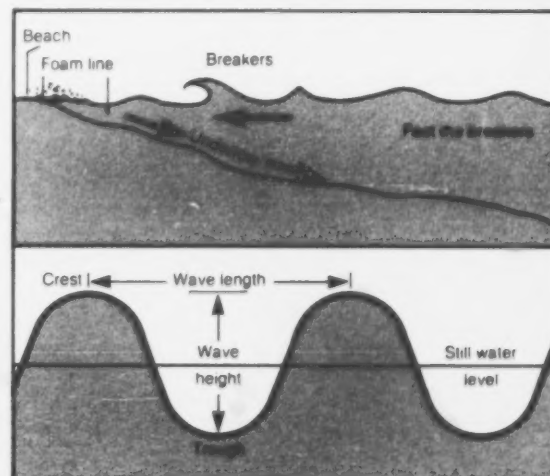
Most of the waves that we are familiar with are caused by wind blowing over the water surface. When the wind is blowing over the waves this is called a **sea**. After the waves produced by the wind have moved far enough away, they become a **swell** which is characterised by regular **surging** movements. These waves sometimes travel thousands of miles to shore, and are then known as **surf**.

The lowest part of a wave is called a **trough**. The highest part is called the **crest**. The **wave height** is the distance between the trough and crest. If the surf report says the waves are breaking one metre, it is the wave height that is being measured. **Wave length** is the distance between two successive crests.

There is a wave form visible from the surface of the water but that's not all that a wave consists of. Not all of the wave is above the surface. The wave energy goes down from the crest to the trough. The water itself in the open ocean does not move forward, **only the energy of the waves moves**. The diagram at the right, shows the energy building up (1 and 2) and peaking as a wave crest (3); then, the energy passes on and causes a crest to drop (4) and creates a trough (5). The surfer will feel like he is on a swing —moving but going nowhere. However, when the wave nears the shore and touches the seabottom, it starts to drag. This forces the water to pile up until the face becomes so steep that it spills over, or **breaks**. The water moves toward shore and takes the surfboard with it.

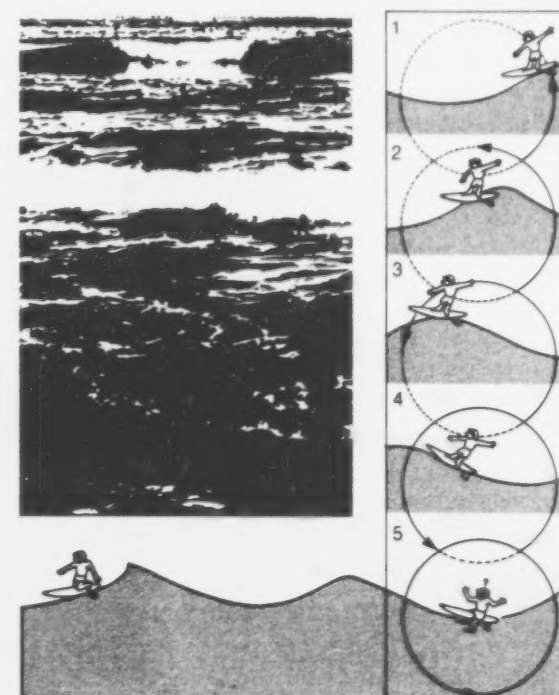
Then the water rushes back, pulling the sand along with it. This backward pull is called an **undertow**. This undertow can pull out and drown even the best swimmers.

In the diagrams on the right, what is happening to the surfer who paddled out too far? Will he be able to catch a wave out there? Where would be the best place for him to be?



How big a wave gets depends on how strong the wind blows, how long it blows and also depends on the exact length of water over which it blows. Under the right circumstances, monstrous waves can be formed, sometimes up to 30 metres high.

There are other kinds of waves besides waves caused by the wind. **Tsunamis** or so-called 'tidal waves' are caused by large undersea **earthquakes**. These waves cross the ocean as long low waves, so low that ships at sea do not even feel them. When they come into shallow water near a coastline, they rise to great heights and can cause a great deal of destruction. Hawaii is very prone to this type of wave because it is in the middle of the Pacific basin and can be attacked by tsunami waves from such places as Chile, Alaska, or Japan.



3.2.2 Beach Erosion

Waves are constantly at work to **reshape** coastlines. When a wave enters shallower and shallower water, the back and forth motion of the water on the seabed becomes greater. This water motion is able to push the sand back and forth, and if the water motion is strong enough, it can also push large stones and rocks.

When the waves approach a shoreline so that the **crests and troughs** of the waves are **parallel** to the coastline, there is a tendency for the sand to be pushed directly on to the beach. This is because the waves steepen and break and rush up the beach, carrying within them some quantity of sand.

If the waves **approach** the shoreline at an angle, then the sand is not pushed directly up the beach, but is also pushed along the beach. Then, when the wave **recedes**, it will also carry back some sand. If we look at just one grain of sand, we see that it is pushed up the beach at an angle and comes back. Then the next wave takes over, and it pushes the grain of sand up the beach, and so on. This grain of sand is moved about in a zig-zag motion. It is this continual **process** that is able to little by little move and reshape large beaches



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The Waves

There it comes creeping along the ocean,
Like a layer of blue clothes moving,
With a rugged surface towards the reef.

There it makes a vibrating sound,
Crashing on rocks along the shore,
Shaking them with a vicious force.

Now it carries the huge logs to shore,
Like a number of canoes racing,
Without their sails and outriggers.

There it breaks furiously along the beach,
With a peculiar sound,
And runs back away
To its homeland area.

Naime Lohia, Iarowan High School — Central District, Papua New Guinea.



3.2.3 Currents

Have you ever thought of placing a note in a sealed bottle and setting it adrift in the sea? We know the bottle will go somewhere because the waters of the ocean move. The great bodies of water that move across the oceans are called **currents**.

We saw in the previous section that the early sailors used their knowledge of currents to help them navigate.

What is it that causes the currents to flow?

The surface ocean currents are caused by a combination of three forces:

- sun's heat
- earth's movement
- wind patterns

The combination of these three forces produces a pattern of surface currents which circulate: clockwise in the northern hemisphere and anti-clockwise in the southern hemisphere. (Next time you let the plug out of the bath observe the spinning of the water. Is it clockwise or anti-clockwise?)

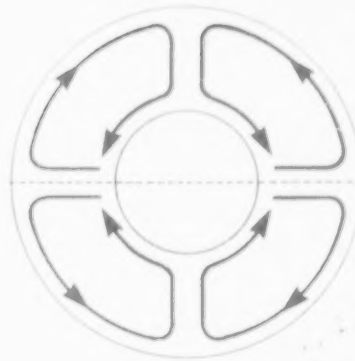


Diagram 1

Sun's rays heat the equatorial seas, which expand and flow 'downhill' towards the Poles. The polar waters sink, flowing towards the equator on the sea floor

Diagram 2

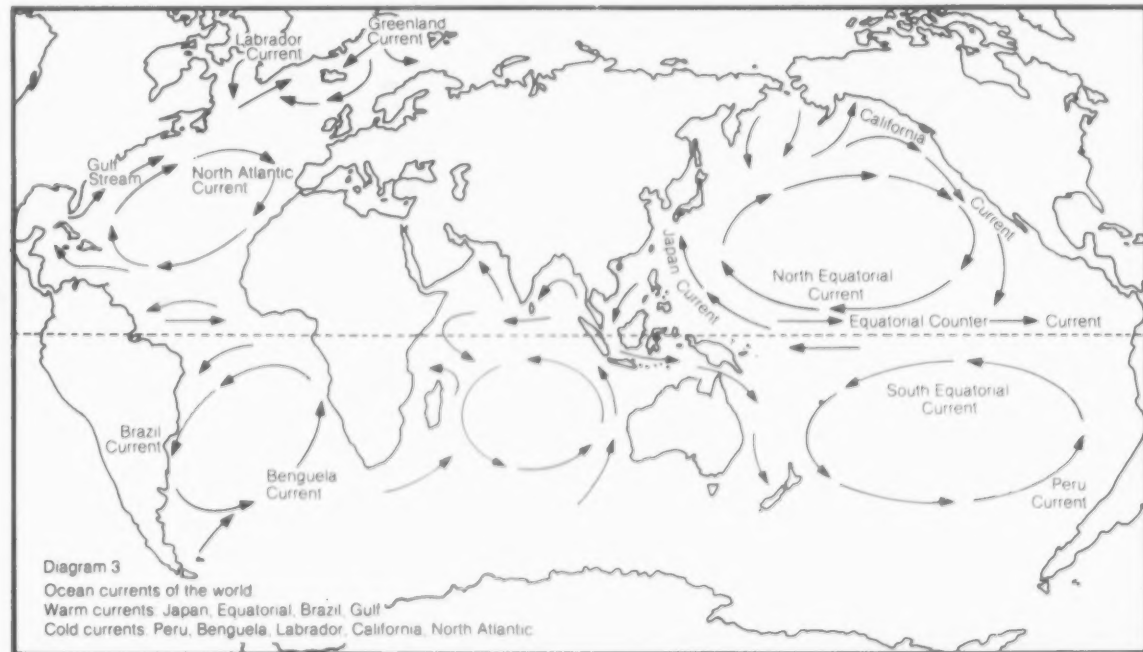


Sun's heat

Because the sun's rays travel less distance through the atmosphere to reach the earth's surface at the equator than they do to reach the poles, they don't lose as much heat to the atmosphere. This means that the sun's rays bring more heat to the tropical seas than to the polar seas. Because warm water is less dense than cold water it rises to the surface of the ocean. Thus the warmer tropical seas at the Equator become 'higher' and flow out towards the Poles. The denser polar waters sink and flow towards the equator on the sea floor.

If cold water flows toward the Equator and warm water flows toward the Poles then this should cause the ocean currents to flow in straight paths, colliding when they meet. (Diagram 2)

But the world map shows the currents flowing in giant circles. The currents have changed directions from that which we would logically expect. Why? (Diagram 3).

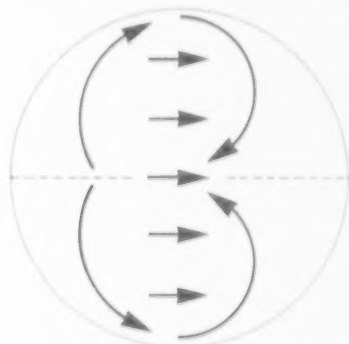


Earth's movement

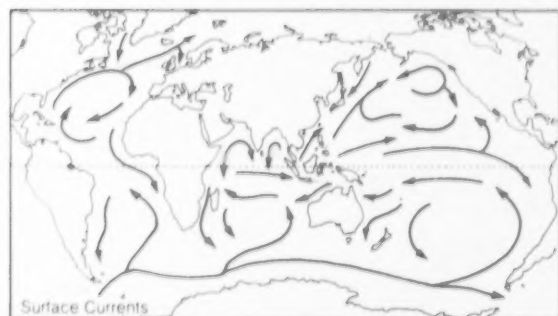
The answer is that the earth's movement deflects the currents and causes them to travel in a curved path. The earth is a sphere which spins to the east at a constant speed. Because a place on the equator travels further in a day than a place closer to the poles, the place nearer the equator travels faster.

This means that something moving from the equator towards the poles (and vice versa) will not move on a straight line — it will be slightly curved.

We can, of course, easily adjust the course of ships, planes and cars, but we can't adjust the courses of winds and ocean currents. In the northern hemisphere these are deflected to the right, and in the southern hemisphere to the left. This is called the **Coriolis effect**, after G. G. de Coriolis, a French mathematician who first discovered it in 1835.



Coriolis effect, caused by the earth's rotation, deflects winds and currents to the right in the Northern Hemisphere, to the left in the Southern Hemisphere.



Surface Currents



Direction of Winds

Wind belts, affected by the earth's spin and solar heat, drive seas — from the east in the tropics (trade winds), from the west in high latitudes (westerlies).

Wind patterns

Constant wind movement in certain directions is an important element in the movement of surface currents. Wind is the movement of air from areas of high pressure to areas of low pressure. In the earth's atmosphere there are several belts of high pressure and low pressure. There is a pattern of **prevailing winds** which move from the high pressure belts towards the nearby low pressure belts.

Winds are named by the direction **from** which they blow. Prevailing winds are from the east in the tropics (trade winds, the easterlies), from the west in the mid-latitudes (roaring forties, the westerlies) and from the east in the polar areas. In between these systems are zones where there is very little wind, notably the doldrums (equatorial low), horse latitudes (subtropical highs) and polar fronts.

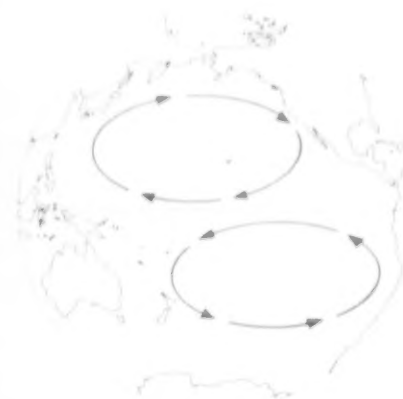
See what you can find out about the importance of these different wind belts for early sailing ships. Try to find out more about the names they were commonly given — i.e. roaring forties, trades, horse latitudes, doldrums. Why are these wind patterns of less importance now to ships at sea?

How Have People Studied and Mapped Surface Currents?

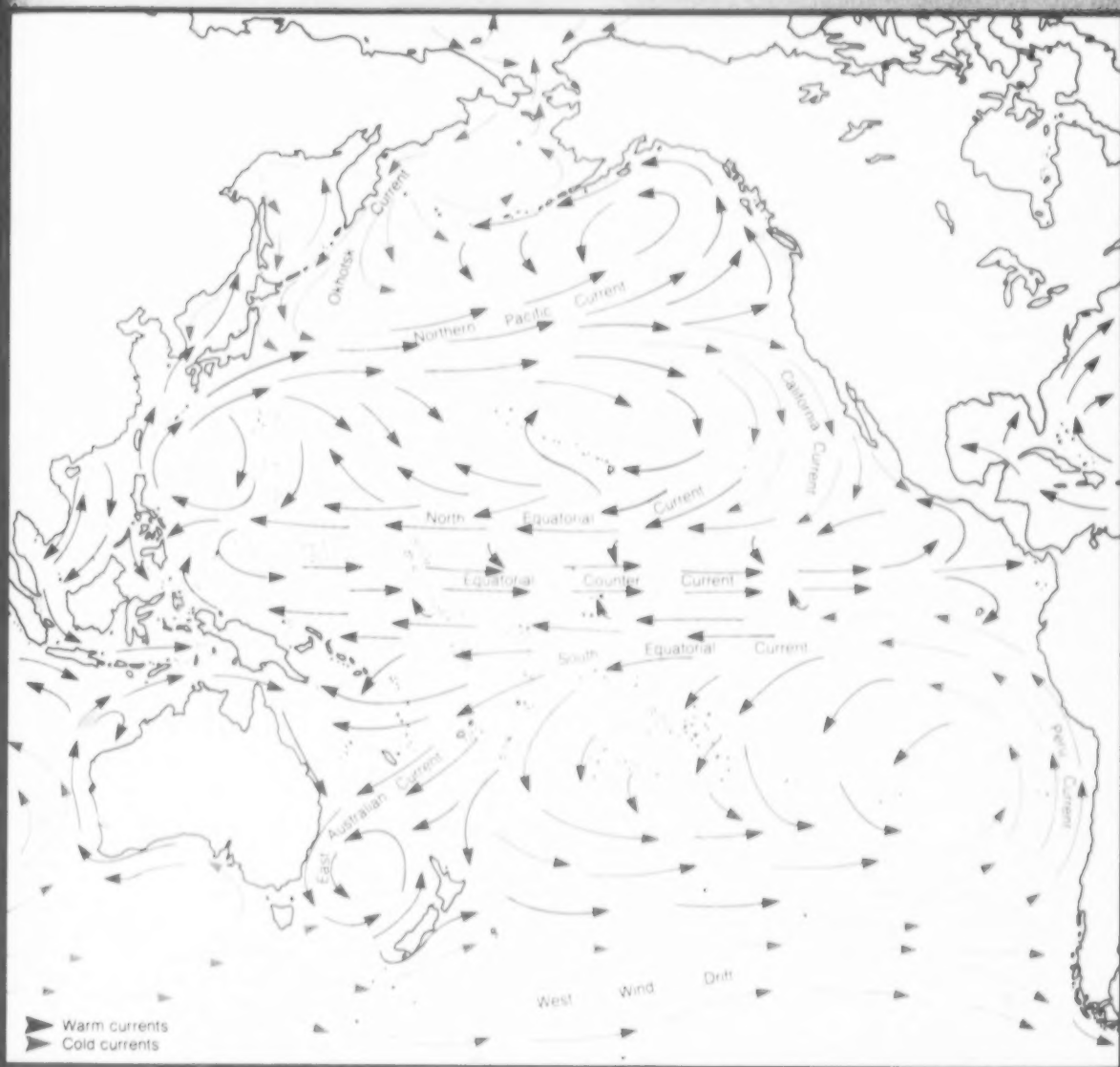
It is not difficult to study the direction of water movement along a coastal area. But how have people studied current movements in the open ocean?

Surface currents have been studied by using **drift cards** and **drift bottles**. Both work on the same principle — they are put into the sea at different points and marked with the time and place of release and the name of the sender. The finder is asked to contact the sender and to indicate where the bottle or card was found. On the whole drift cards have replaced drift bottles. Can you suggest why?

The era of **satellites** has enabled us to gather much more information without having to rely on the goodwill of people who discover drift cards and bottles. Large drifting buoys fitted with transmitters relay information to orbiting satellites which then beam the information back to earth receiving stations.



Combination of three forces — sun's heat, Coriolis effect, winds — circulates sea currents clockwise in the Northern Hemisphere, anti-clockwise in the Southern.



The currents of the Pacific Ocean. These great ocean currents move clockwise in the Northern Hemisphere and counterclockwise in the Southern.

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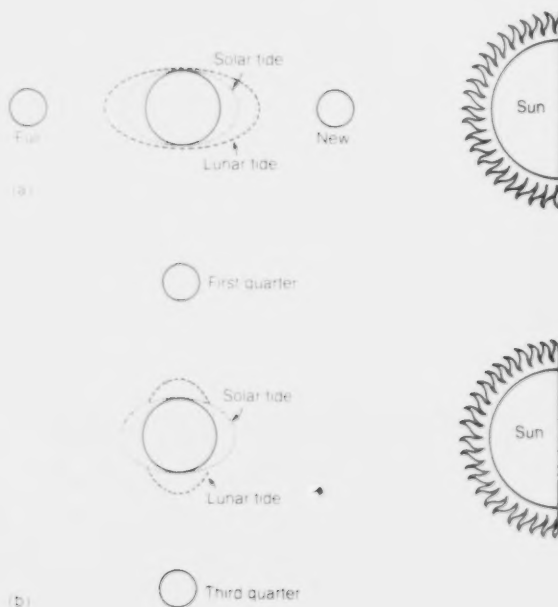
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3.2.4 Tides

Tides are the most familiar of ocean water movements.

Tides are the regular changes in sea level which we know as high tide and low tide.

Tides are caused by the moon and sun exerting a pull of **gravity** on the earth. Because the moon is closer to the earth, its pull is more important than that of the sun. **High tides** occur when the moon is almost directly overhead, at which time its gravitational pull is the strongest, and also when the moon is directly on the other side of the earth. It takes 24 hours 50 minutes for the moon to pass over the same spot on the earth's surface, so high tides occur every 12 hours and 25 minutes.



(a) When the moon is new or full, the solar and lunar tides are in the same direction, giving the extra large 'spring' tides.

(b) When the moon is at first or third quarter, the solar and lunar tides are at 90° to each other, yielding little net tides, called 'neap' tides.



In open ocean waters the **difference between high and low tide** is small — only 30-60 centimetres. In coastal ocean waters, the difference is much more marked, and especially along the shore line.

Shallow coastal areas (gulfs and bays) can produce tide ranges of up to ten metres or more, although average shoreline tidal ranges are between two and four metres.

The **tidal range** of any place depends on the shape of the coast and the shape of the ocean bottom offshore. Weather conditions, particularly

atmospheric pressure, can also affect the expected tidal range.

Spring tides are exceptionally high and low tides (i.e. there is a greater difference between high and low tide). These occur when the moon and sun are in line with each other and they work together (new moon and full moon).

Neap tides are relatively small tides which occur when the moon and sun are at right angles to each other (first and last quarter).

3.2.5 The Intertidal Zone

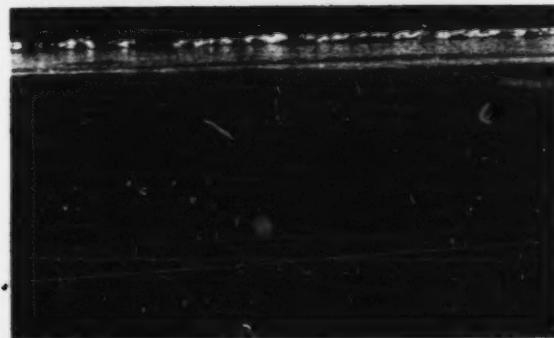
The intertidal zone is the part of the shore line between high and low tide mark. This area is alternatively covered and uncovered each day. Plants and animals living in the intertidal zone must be able to cope with being exposed to both air and water and sometimes also to heavy surf waves.

The intertidal shoreline provides the home for a wide variety of marine plants and animals. Important intertidal areas are:

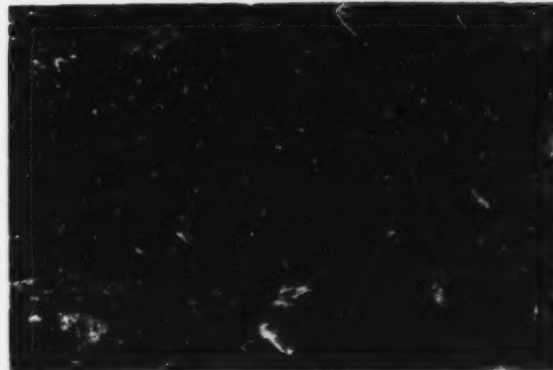
- rocky shorelines
- sandy shorelines
- mangrove swamps



Mangrove swamp



Sandy shoreline



Rocky shoreline

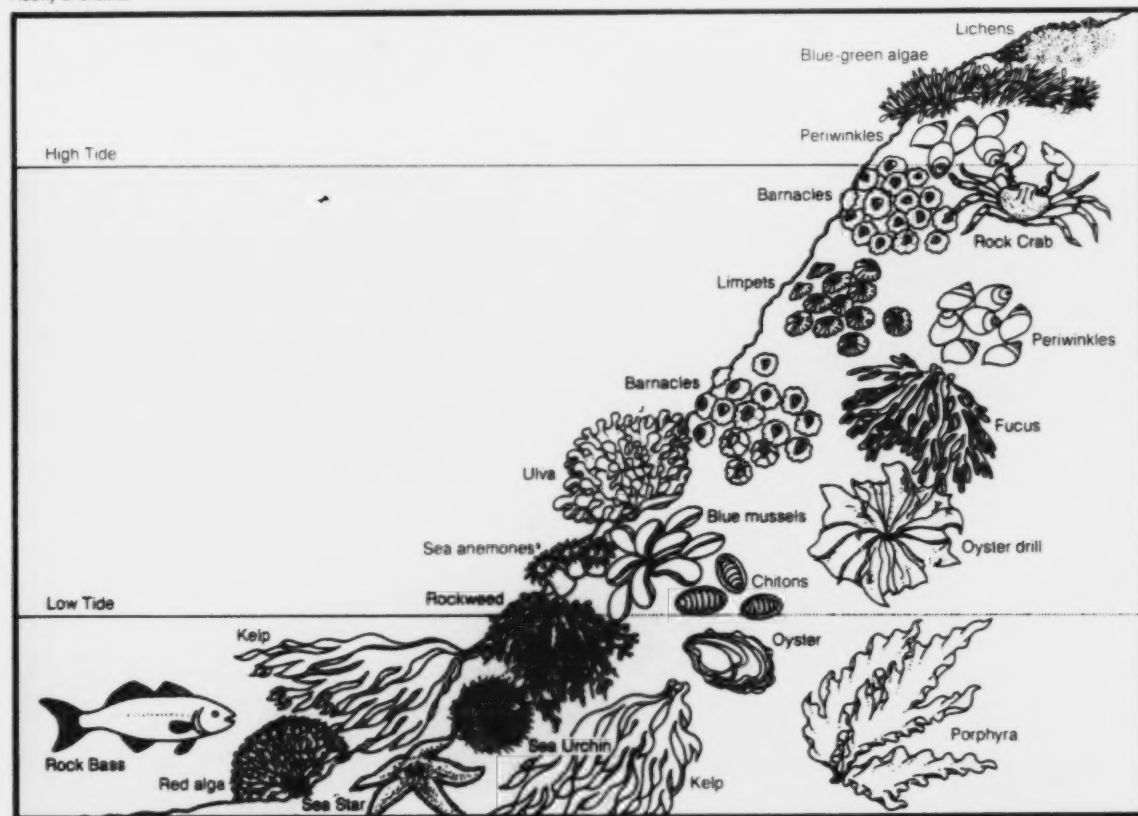
On a Rocky Shoreline

If you have been to a rocky shoreline, you will have had an opportunity to see the sort of places plants and animals live.

The following diagram shows the intertidal zone on a rocky shore.

Describe the sorts of plants and animals shown on the diagram. Group them into (i) those living below low tide (ii) those between low and high tide and (iii) those living above high tide.

What differences can you see in the situation of the limpet compared to that of the sea anemone and the kelp? Why might the kelp not be able to live where the limpets do?



Why the Ocean Is Salty

A Filipino Legend

Now you must know that in the first times the ocean was all pure fresh water, for that was before salt had been added. It is said that the oceans had been formed by the tears of unhappy goddesses.

Living at this time was the tall and handsome giant Ang-ngalo (Ung nga low) first man of all the Ilocanos (ee low ka nos). Ang-ngalo had been ordered by the Supreme One to create the world. And so Ang-ngalo was very busy at his work, creating mountains and digging caves where the people might live. These caves he protected from Angin (ung.in), the god of the wind, by building deep precipices and growing great trees to hide them.

One morning when the sun shone brightly upon the world, the great giant wandered forth from one of his caves in a lofty mountain peak. When he looked up he saw a beautiful goddess waving to him from the other side of the ocean. With a few mighty strides he crossed the ocean toward her, leaving behind him deep caverns in the ocean in the place of his footprints.

When Ang-ngalo reached the other side he saw that this fair maiden was Sipnget (Sip.nyet), goddess of the dark.

'Why have you summoned me, Sipnget?' he asked.

'Because you are a great builder, Ang-ngalo,' she answered. 'I am goddess of the dark and must remain always in my dark place in heaven. I have grown weary of the dark and want to leave it. Ang-ngalo, will you not build for me a palace upon this sunny spot? It must be a palace as white as the sun, and it must be built of bricks as white as the snow!'

Ang-ngalo promised her that he would do his best for her. But he knew not where to find that which the goddess had asked for, bricks as white as the snow! He did not wish to disappoint her, so he pondered long over his problem.

At last he thought of salt, and indeed that was the only white thing there was on the earth when the world was new. So he set out to find Asin (A.sin) ruler of the Salt Kingdom. And when he found him and had made known his request, Asin made Ang-ngalo very



happy by giving him bricks of salt which were as white as the snow.

But now the bricks had to be carried to the other side of the ocean. So the giant builder erected bamboo bridges which were so immense that they stretched clear across the ocean. Then he employed millions of men who worked day and night carrying the salt bricks across the ocean to the spot where Sipnget wished her palace to be.

But alas, the pure white bricks of salt were not all destined to reach the other side! For, with all the great activity which went on above her, the ocean became

impatient. Her rest was being constantly disturbed, and she grumbled and fretted in vain. Daily and far into the night the commotion continued. At last the ocean revolted! With a mighty splash and roar she humped her back and sent up tremendous waves. And the bamboo bridges which Ang-ngalo had built, and the salt bricks themselves, all went down, down into the ocean's depths and were gone forever.

And what happened to the white bricks of salt? Well, they melted and from that time forth the ocean has been salty.

3.3 What Makes up Sea Water?

In the previous sections we looked at the movements of ocean waters. In this section we look at the actual substance — ocean water and the things that are dissolved in it.

Sea water is made up of a number of different **salts** and **trace elements** (including gold) but, apart from water, the main 'ingredient' is of course sodium chloride or common table salt.

Do You Know?

- Each kilogram of sea water contains about 35 grams of dissolved material in it.
- If all the salt in the ocean could be removed and spread evenly over the land surface, it would form a layer about the height of a 40 story building.

Scientists believe that when the ocean water was first formed it was fresh. How then did it become salty? The theory is that as rivers on land flowed over the earth's and rocks, mineral salts were dissolved and washed out to sea. One piece of evidence supporting this theory is that over the years the seas have been getting saltier at a steady rate.

The **salinity** of the sea, that is its saltiness, varies from place to place. We usually measure salinity in 'parts per thousand' — that is, how many grams of salts are dissolved in each thousand grams of salt water.

The average salinity of the world's oceans is 35 parts per thousand. Variations occur in situations like these:

- **Low salinity** can be found near land where large rivers bring a lot of fresh water into the ocean and dilute it. Salinity can be as low as 5 parts per thousand.
- **Normal salinity** can be found in mid-ocean areas where the surface waters of the ocean don't move very much. The volume of the open ocean is so great that it is not affected by the run-off from rivers or evaporation and therefore remains constant.
- **Higher salinity** is found in rock pools and lagoons where water is trapped. It is also found in areas of high temperature such as the Utah

Desert (The Great Salt Lake) and Israel (The Dead Sea). Rapid evaporation has made these two bodies the saltiest in the world.

Small differences in salinity can change the **density** of a body of water. The greater the weight of salts dissolved in the water, the more dense the water is. The Dead Sea is so dense that you would have no trouble staying afloat in it, even if you couldn't swim. Can you answer the following questions?

- Why would oceans in the southern hemisphere be more saline than those of the northern hemisphere?
- Why would the highest salinities be recorded in subtropical regions, and lower salinities near the equator and poles?
- Why might salinity sometimes be as high as 40 parts per thousand in the Red Sea and the Persian Gulf, although land is very close?

What Else is Dissolved in Sea Water?

The salts in sea water are inorganic — that is, they are not from the bodies of living plants or animals.

Besides dissolved inorganic salts the sea also contains small amounts of **dissolved organic materials** which come from both living and dead plants and animals.

You will also find that all the **gases** in the atmosphere are present in small quantities dissolved in sea water. **Oxygen**, the most important gas for living organisms, is concentrated near the surface of the ocean. You find more dissolved gases in the cooler waters. Can you explain why this should be the case?

Dissolved gases are also more plentiful where the water is not calm, such as coastal areas. As ocean life depends on these gases, there is more life where there are more dissolved gases. Can you remember how fish and marine animals obtain their oxygen?

Composition of Sea Water

Major and Minor Salts 34.5 parts per thousand

Major Salts

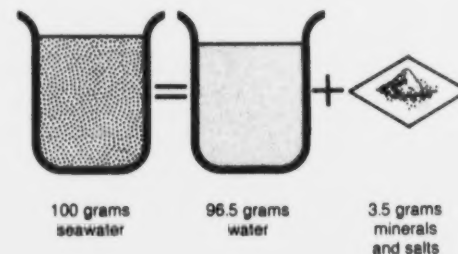
sodium chloride	23.0
magnesium chloride	5.0
sodium sulphate	4.0
calcium chloride	1.0
potassium chloride	0.7
Total	33.7

Minor Salts

include salts of bromine, strontium, carbon, boron, silicon, phosphorus, fluorine.

Total 0.8

Trace Elements — In addition to the major and minor salts, most elements that occur naturally on the earth are present in some quantity in the sea water as trace elements, although they may be in extremely small quantities. There are more than 70 naturally occurring elements.



*the cooler the water the more gas it can hold.

4.0 Exploring the Depths of the Ocean

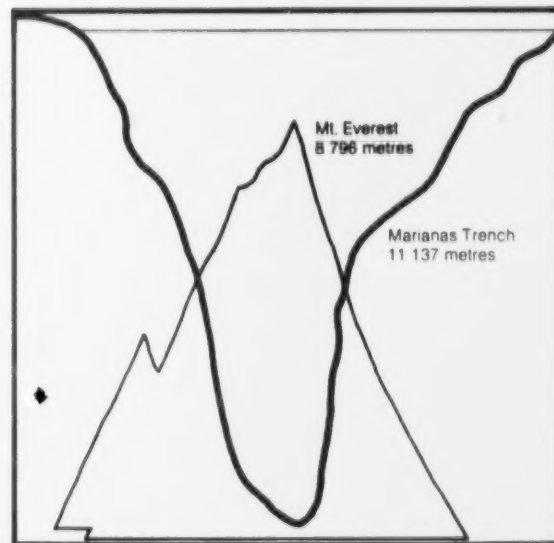
Do you know that there are mountains in the sea? Just as the earth's surface above water has valleys and mountains, the ocean floor has canyons and mountains. For example, the Hawaiian Islands are really the peaks of old volcanoes which rise from the floor of the Pacific Ocean.

Not only are there high peaks, there are also very deep V-shaped canyons or trenches, some much deeper than the Grand Canyon of Arizona.

Some Deep Ocean Trenches

Name	Located Near	Depth
Marianas	Guam	11 137 metres
Philippine	Philippines	10 436 metres
Nares	Puerto Rico	9 156 metres
Middle America	Eastern Pacific	6 622 metres

So deep is the Marianas Trench that if Mt. Everest were placed in it, its peak would be covered by several thousand metres of water.



4.1 The Shape of the Ocean Floor

There are two main areas of ocean floor — continental margin and deep ocean. These two areas correspond with the two major ocean habitats — coastal ocean waters and open ocean waters.

4.1.1 Continental Margin — Under the Coastal Ocean Waters

The continents don't just end at low tide level. Around the edge of the continents there is a margin of continental rock. This margin consists of:

- continental shelf
- continental slope
- continental rise

The continental margin covers only about 8% of the ocean floor. The **continental shelf** varies in width from place to place — from almost nothing up to 1500 kilometres. The shelf slopes very gently downwards from low tide so that water over continental shelves is usually quite shallow. An average depth at the outer edge of the shelf is 130 metres. Sands, muds and gravels usually cover the surface of continental shelves. These sands and muds come to the ocean from the rivers and coasts.

In some places, especially river mouths, deep submarine canyons cut across the surface of the shelves. They are scoured out by the water coming into the sea from the rivers.

Shelf areas, to date, have been the most productive areas of the ocean for mining and fishing, being shallowest and closest to the shore. At the outer edge of the continental shelf, there is a sharp break to the **continental slope** (look at your diagram on p. 55). At the base of the continental slope, the **continental rise** slopes gently to the deep ocean floor where sediments from the continental slope have gathered.

4.1.2 Deep Ocean Floor — Under the Open Ocean Waters

The deep ocean floor covers by far the largest area of the ocean floor — it lies under approximately 92% of all ocean waters.

Most of the deep ocean floor is **abyssal plain** — which means literally, 'flat land at great depth'. 75% of the ocean floor is abyssal plain. These plains are extremely flat because very fine sediments carried to sea in water currents have gradually settled out in the still water of the ocean bottom. They have blanketed over any irregular shapes which once might have existed on the ocean floor. The sediments do this in much the same way as a fresh snow fall covers over and masks the detailed shapes of surface features on the earth.

The abyssal plains are broken at different points by **submarine mountains** — all of which are volcanic in origin. These volcanic mountains sometimes rise to the surface of the oceans, either as **island arcs** associated with ocean trenches (such as the Kurile, Aleutian and Mariana Islands) or **shield volcanoes** rising over hot spots (weak areas) in the earth's crust (such as the Hawaiian Islands).

Sometimes the submarine mountains do not reach to the ocean's surface, and form drowned peaks called **seamounts** and wave-eroded flat topped seamounts called **guyots**.

A continuous mid-ocean ridge runs for some 55 000 kilometres under the earth's oceans. The mid ocean ridge stands some 1-3 kilometres above the



The Ocean Floor

abyssal plain and is on average 1500 kilometres across. At the middle of the ridge is a deep rift about 1.6 kilometres deep and between 37-48 kilometres wide.

Contrary to what the ocean explorers were expecting, the deepest part of the ocean is not in the centre! The deepest part of the ocean is found in the **ocean trenches** which are usually close to the edge of the

continents. In the Pacific Ocean there are trenches extending for thousands of kilometres almost around the entire rim of the ocean. Ocean trenches are about 3-4 kilometres deeper than the surrounding ocean. The Challenger Deep, mentioned earlier, is one such ocean trench, located in the north-west Pacific.

4.2 Deep Water

How does deep water differ from shallow water? This section looks at the special characteristics of deep water in terms of difference in

- light,
- temperature,
- salinity (salt content), and
- pressure.

4.2.1 Light

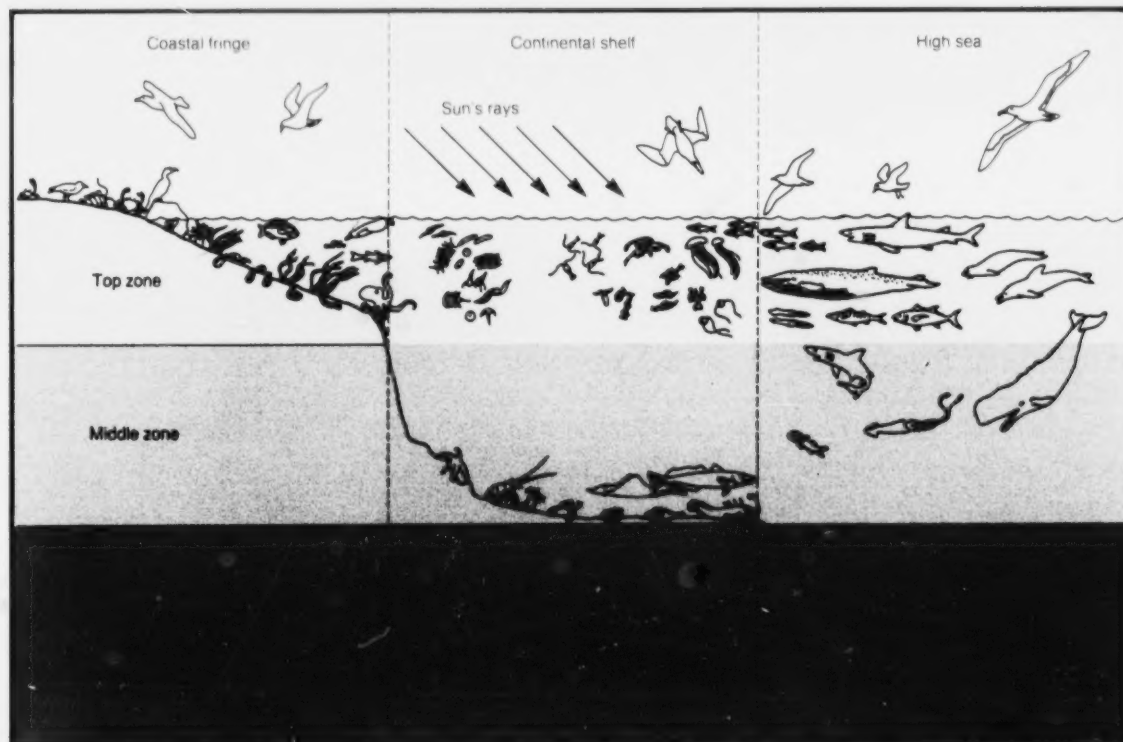
Going from the surface down into the ocean is like going from day to twilight to night. This is because the sun's rays do not penetrate the deep ocean waters. The ocean absorbs the sun's rays in a way that the air does not, so that the sun's rays only penetrate into the upper layer of the ocean.

Light from the sun consists of seven colours — red, orange, yellow, green, blue, indigo and violet. When light passes into water, some of these colours are absorbed before others, so the light at different depths has different qualities. The importance of this for plant life is described below.

The ocean can be divided into three vertical zones on the basis of how much light it receives:

1. The **top zone** receives sufficient light for plants to grow. It extends from the surface of the ocean to about 20 metres in middle latitudes in summer, and to about 50 metres close to the equator. How could you account for the difference?
2. The **middle zone**, the so called 'twilight' zone, receives some light, but not sufficient for plants. It extends from the bottom of the top zone to about 1000 metres.
3. The **bottom zone** gets no light except that which is given out by organisms which live in this zone. It extends from the bottom of the middle zone to the ocean floor.

Is it likely that the sense of vision is as important to sea animals as it is to humans?



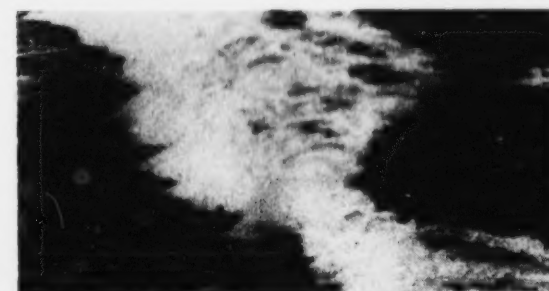
4.2.2 Temperature

Deep water is colder since only the top layer of the ocean is heated directly from the sun. Deeper waters in all parts of the ocean are fairly constantly cold — mostly 2-3°C and nearer the poles close enough to 0°C.

4.2.3 Salinity

The **salinity** of the water does not change because of depth. Because different currents have different salinities, the salinity of a body of sea water below the

surface is determined largely by where that water comes from.



4.2.4. Pressure

Increased **pressure** is one of the most notable characteristics of deep water. Pressure at the very bottom of the ocean is enough to crush the largest ships.

If you have ever tried carrying a heavy water jug, you will know quite well how heavy a quantity of water can be. If you dived to a depth of 10 metres, you would have a column of water 10 metres high pressing down on top of you. Pressure increases at the rate of one atmosphere for every 10 metres of depth. Imagine you dived to 20, 30, 60 metres. What pressure would you experience at each of these depths? The Challenger Deep in the Marianas Trench at 11 137 metres is the deepest part of the ocean. Fish live there. What pressure do they live at?

You can see the effect of increased water pressure with depth by filling a vertical pipe with water and puncturing it in two or three places.

What do you notice about how the water comes out of the different holes?

You may have heard of deep sea divers who suffered from 'the bends'. Divers who come to the surface too quickly are liable to suffer bends — which is a kind of severe cramp — because they have not allowed sufficient time for their bodies to become accustomed to a lessening of pressure as they come to the surface. When people go deep under water, their bodies can become accustomed to the increased water pressure on them, but if the pressure is removed too quickly (by coming up too quickly) nitrogen, which builds up in the blood stream at depths, is released too rapidly, causing the cramps. The bends can often be cured by people going down again and coming up more slowly, or going into a recompression chamber.

Why don't whales suffer from the bends?



Recompression chamber

4.3 Exploring the Depths

How do we know what is on the ocean floor?

How have people explored and measured the depths of the ocean?

We have found out about ocean depths:

- by studying things which are washed up on shore (flotsam)
- by remote control (studying the ocean from above its surface, for example, by ship technology)
- by going down into the ocean

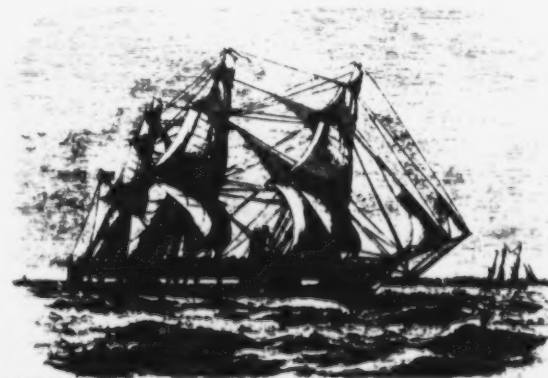
Oceanography is the scientific study of the ocean. Oceanographers (people who study the ocean) have built an increased body of information and understanding about the ocean environment but there are still many things to explore.



Halley's lead-weighted diving bell of 1690 (shown cut away) was a hollow conical vessel open at the bottom and supplied with air through a leather pipe from an air-filled barrel.

4.3.1 Measuring the Depth of the Ocean

In the 1870s C. W. Thomson and John Murray, headed a five year study that lasted from 1872 until 1876. Murray and Thomson's methods might seem rather slow and laborious by modern standards but they were effective for the pioneers. To measure the depths of the ocean, they let down a length of line, knotted at regular intervals, until it reached the bottom.

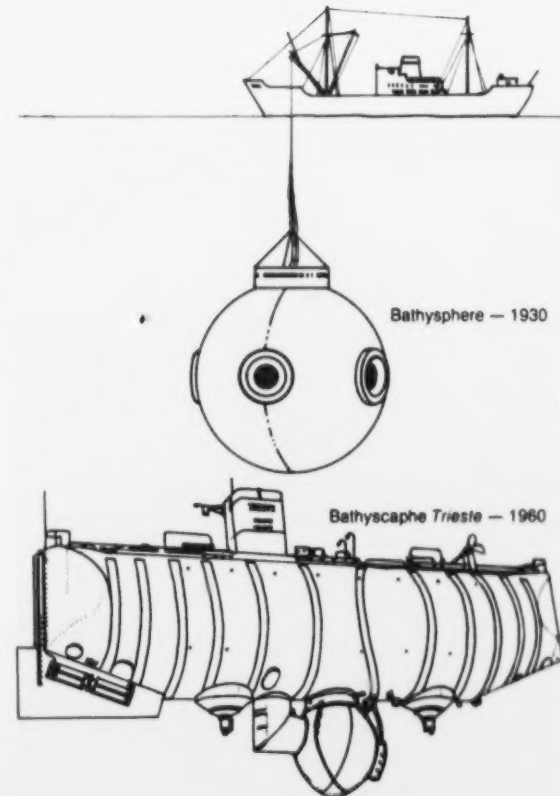


HMS Challenger

In 1906 the echo sounder was patented. This enabled oceanographers to measure the ocean depth much more quickly. Sound travels extremely well in water, much faster than in air. Sound waves are sent from an echo sounding system on board a ship and these bounce off a reflecting layer, such as the bottom of the ocean, and return to their source as an echo. As we can measure the speed of sound in water, we can tell how deep the ocean is if we know how long it takes for the echo to return.

Can you work it out? Sound travels at 1445 metres per second in water. If it takes four seconds for the echo to be heard, how deep is the ocean?

In 1930 Dr. William Beebe went more than 1000 metres down into the Atlantic Ocean. He was lowered



Bathysphere — 1930

Bathyscaphe Trieste — 1960

in a **bathysphere**, a giant steel ball with heavy windows. The bathysphere was tied to a ship by cables and air hoses supplied air. The next device developed for underwater exploration was the **bathyscaphe**. This was a steel sphere hung from a very large float. Underwater the bathyscaphe used propellers to move about. In 1960, Jacques Piccard lowered a bathyscaphe to the bottom of the Pacific Ocean — 18 600 metres.

Recently experiments have been carried out in living at the bottom of the sea. The famous underwater explorer Jacques Cousteau led a team of six French aquanauts who spend 27 days at the bottom of the Mediterranean, approximately 100 metres below sea level.

4.4 A City Beneath the Sea?

A **habitat** is a word we use to describe where plants and animals live — in other words, their habitat is their home environment.

Many different things combine to make a habitat, and if some of these are changed, particular plants and animals may not be able to survive.

In order to see if people could live on the floor of the ocean, we need to know something about the natural habitat on land. In other words, what do human beings need to survive? On a sheet of paper describe our habitat, including what we must get from our environment for:

- breathing,
- eating,
- resting,
- keeping our body warm,
- seeing,
- communication, and
- mobility (letting us move easily).

Discuss the list with others in the class and draw up a list of things in our habitat.

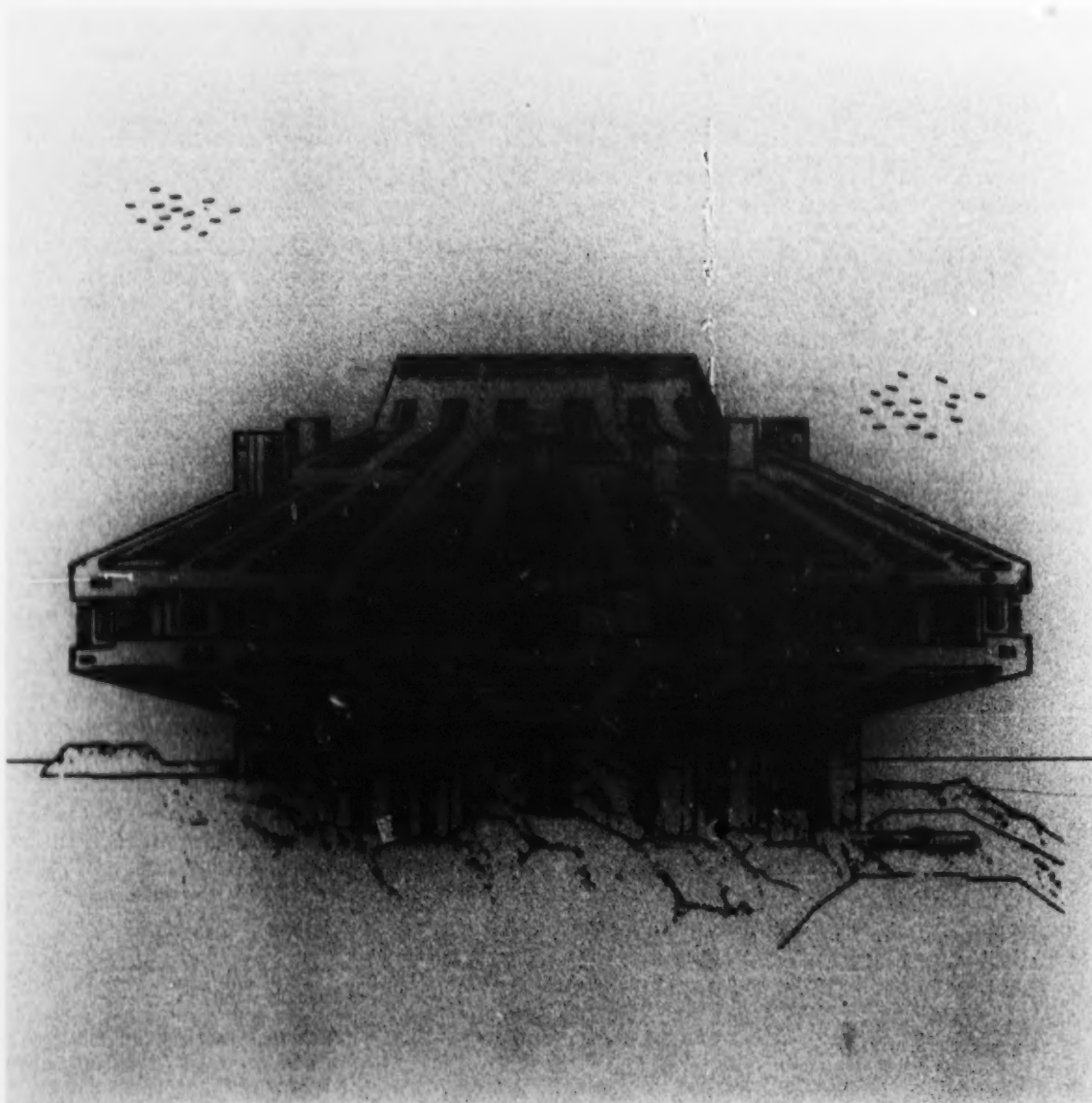
People have proved themselves very adaptable; they can live in a much greater variety of places than almost any other organism, mainly because they have developed technology to help them.

Could people live at the bottom of the ocean?

To answer this, you will need:

1. to work out what the environment of the floor of the ocean is like,
2. to decide if people could survive there without any adaptations, and
3. if not, what adaptations could help them survive there.

Use diagram on page 55 to help you describe the floor of the ocean.



A city beneath the sea

Glossary of Terms

abyssal	Those regions of the ocean bottom that lie at depths between about 3.5 km and 6 km.
abyssal plain	Extensive flat regions of the deep ocean floor, usually bordering on continental margins.
adaptation	The process of changing so as to suit new conditions.
algae	Plants that grow in fresh and/or salt water, e.g. seaweed
Archimedes principle	Any object placed in a liquid is pushed upwards by a force that is equal to the weight of the liquid that the object displaces.
archipelago	A sea studded with many islands.
arthropods	Animals with jointed legs and external skeletons, e.g. crustacea and insects.
atoll	A coral island consisting of a ring-shaped reef enclosing a lagoon.
bathyscaphe	A powered diving sphere used for deep-sea exploration.
bathysphere	A sphere which is used for deep-sea observation.
benthos	All organisms that are attached to, live on, or live in the ocean bottom.
buoyancy	The ability of an object to rise or float due to the forces of the fluid it is in or on.
cartilaginous fish	Fish that don't have a bony skeleton but one made up of cartilage, a pliant, gristle-like substance. Examples are sharks, skates and rays.
circumnavigate	To navigate entirely around.
chlorophyll	A pigment found in plants.

commercial	To do with trade; produced for mass consumption with profit as a primary aim.
compass	An instrument of navigation for determining the magnetic meridian or a person's direction in relation to it. It consists of a magnetised needle turning on a pivot.
continental margin	The edge of a continent bordering an ocean basin, usually considered to include the coast, continental shelf, continental slope and continental rise.
continental shelf	The edge of continental land masses submerged under water, at an average depth of 130 metres. Width varies from almost nothing to up to 1500 km.
continental rise	The wedge of sediments deposited at the base of the continental slope.
continental slope	The region of the ocean bottom beginning at the outer edge of the continental shelf and plummeting downward at a relatively steep angle to a depth of 3-4 km.
copepods	Small arthropods resembling very tiny shrimp that feed heavily on microscopic plants.
Coriolis effect	The apparent deflection of moving bodies from their expected straight line motion caused by the rotation of the observer's reference frame.
crest	The highest part of a wave.
current	Any large-scale sustained movement in a fluid mass.
debris	The remains of anything broken down or destroyed; ruins, wreck, rubbish formed by destructive operations.

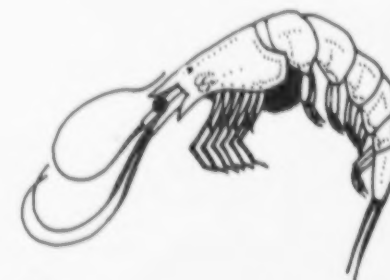
deep ocean channels	Channels found on the deep ocean bottom resembling large river beds; typically two km wide and 100 or 200 metres deep.
deep waters	Those water masses originally formed in polar regions that now are found in the deepest regions of the ocean, usually below 2-3 km depth.
demersal	Fish that live on or near the ocean floor.
density	Compactness, the amount of matter per unit of bulk or volume. Usually measured in units of grams per cubic centimetre.
diatoms	Single-celled microscopic marine planktonic plants.
doldrums	The region of the earth near the equator characterised by relatively light breezes, rising air masses and frequent rainstorms.
dyspepsia	Indigestion.
ebb tide	The part of the tidal cycle when the water is lowering, and water is flowing out of estuaries.
echo	Sound waves that hit a solid object and bounce back.
echo-sounder	An electronic device which defines the ocean depth by sending down sound signals.
ecosystem	A group of plants and animals which are interdependent and within which energy is recycled by animals and plants feeding on each other.
energy	The ability to do work, such as to move something by applying a force to it. Energy comes in many forms, e.g. electrical, chemical, thermal, and so on.

environment	Surroundings; the conditions or influences under which any person or thing lives or is developed.	horse latitudes	Those regions around 30° to 35° North and South latitudes characterised by light surface winds, falling air masses, and arid conditions.	mangroves	Tidal forests; trees growing on the banks of rivers or sea coasts, particularly in estuarine areas.
erosion	The removal of debris, especially rock debris, from its original location through the action of water, wind, gravity, animals and so on.	inorganic	Nonliving; lacking in the organisation or structure of living organisms, composed of inanimate matter, e.g. metals.	mid-ocean ridge	A very long, high range of submarine mountains, typically 1500 or 2000 km wide and 65 000 km long, running through all the world's oceans and occasionally even reaching the surface.
evaporation	The process of changing from liquid to gas.	intercontinental	Between continents.	mineral	A substance occurring in nature having uniform chemical composition and crystal structure.
expediency	Behaviour suitable to surviving or attaining an end, even if that behaviour is not right.	intertidal zone	Part of the shore between high and low tide mark.	mollusc	Invertebrate animal which has a soft, unsegmented body, usually covered with a hard shell of one, two or more pieces; e.g. a scallop or a clam.
fathom	A distance of six feet or 1.83 metres used for measuring the depth of water.	invertebrates	Animals with no backbones.	neap tides	The two times during the month when tidal variations are smallest, occurring when the moon is near first quarter or third quarter.
figurative	Representing something by means of a figure, emblem or likeness; the use of figures of speech such as simile or metaphor, e.g. the British Lion.	island arcs	A chain of volcanic islands found alongside an oceanic trench that is created by the volcanic distillation of oceanic crust.	nekton	Marine organisms capable of fast sustained motion, as opposed to plankton which are not.
flood tide	That part of the tidal cycle when water level is rising, and water is flowing into estuaries.	kava	A Polynesian plant.	nutrient	A substance which is nourishing, that is, which feeds and causes to grow.
food chain	The sequence of animal organisms through which organic matter passes after being produced by a plant.	larvae	The stage which follows the egg in the life cycle of certain organisms, e.g. the grub of an insect. A detached animal embryo, strikingly different in appearance from the adult.	oceanography	The study of the oceans.
foreshore	The intertidal portion of the beach extending from the low tide line up to the high tide line.	latitude	A measure of north-south position on the earth relative to the equator, measured in degrees, with the equator being 0° latitude and the poles at 90° North and South respectively.	ocean trenches	Deep places in the ocean floor.
galleon	Large sailing ship; Spanish ship of war.	literal	According to the exact words; not symbolic or metaphorical.	organic	belonging to or found in the makeup of a living being.
galley	Open ship propelled by oars and sail. Used by ancient Phoenicians, Greeks and Romans.	littoral	Along the shore.	organism	An individual life form composed of a number of mutually dependent parts; any form of animal or plant life.
gravity	A force with which two bodies pull on each other and which is in proportion to their masses.	longitude	A measure of east-west position on the earth measured in degrees east or west of Greenwich, England.	pelagic	Fish which inhabit the surface waters of the oceans, as opposed to benthic organisms which live on or near the ocean bottom.
guyot	Flat topped seamounts.	lunar tide	That component of the tide caused by the moon's gravitation.	pesticide	Any substance, such as chemical poison, used to destroy plants or animals.
habitat	The environment in which a plant or animal naturally grows and lives.	mammal	Warm-blooded animal that produces milk to feed its young, e.g. humans, whales.		

photosynthesis	The process of producing organic matter by using carbon dioxide, water, nutrients and sunlight.
phytoplankton	Plankton that can photosynthesize.
plankton	A collective name for all the forms of floating or drifting organic life found at various depths in the ocean.
Pilmsoll line	A line or mark on the hull of merchant vessels, showing the depth to which they may be submerged by loading.
poi	Hawaiian dish made of the root of the taro, baked, pounded, moistened and fermented.
primary consumers	Ocean organisms that feed off phytoplankton.
primary producers	Phytoplankton. They produce food for other organisms through photosynthesis and do not feed on other plants or animals.
re-cycle	Re-use of waste materials.
salinity	Degree of saltiness in the sea; usually measured in parts per thousand.
seamounts	Mountains found beneath the surface of the sea reaching a height of at least 500 fathoms from its base on the ocean floor.
sediment	The matter which subsides to the bottom of water or any other liquid.
shield volcanoes	A form of submarine mountain that breaks the surface; arising over weak areas in the earth's crust.
solar tides	That component of the tide caused by the sun's gravitation.
spring tides	The two times during the month when tidal variations are greatest. Occurring when the moon is either new or full.

stern	The hind part of a ship or boat.
structure	Arrangement of parts.
submarine mountains	Mountains of volcanic origin, rising from the ocean floor, sometimes breaking the surface to form island arcs or shield volcanoes.
surf	The swell of the sea which breaks upon a shore; the strip of foamy water deposited along a shore by breaking waves.
swell	Large, long parallel waves arising after waves have left the storm centre and have begun to sort themselves out, with the longest, fastest waves taking the lead.
tapa cloth	A kind of unwoven cloth made by Polynesians from the bark of the Paper Mulberry tree.
taro	Polynesian plant used for food.
technology	The science of the practical arts; the knowledge and means used to produce the material necessities of a society.
trace elements	Those elements present in sea water in only very small amounts, and whose concentrations are best measured in parts per billion or less.
trade winds	The prevailing winds that blow toward the west in the tropics, having a slight southward component north of the equator, and a slight northward component south of the equator.
transmitter	A device which sends out electrical signals.
trophic level	A step in the food chain measured in terms of many different organisms that organic material has been in since its original synthesis in plants.
trough	The portion of a wave where the water surface is depressed.

tsunamis	Tidal waves generated by movement of the ocean bottom, such as an earthquake.
twilight zone	200 metres below the surface of ocean waters.
undertow	A current below the surface of the water, moving in a contrary direction to that of the surface current.
upwelling	The rising of deeper ocean waters to the surface.
vegetarian	Lives on vegetable foods; non meat-eating.
vertebrates	Animals with backbones.
wave height	The vertical distance between the lowest point in a trough and the highest point on the neighbouring crest.
wave length	The horizontal distance between any point on one wave and the corresponding point on the next wave, such as from one crest to the next.
zooplankton	Those members of the plankton that are animals.



Glass cosmetic bottle from El-Amarna, Egypt
(Eighteenth Dynasty, c. 1410-1320 BC)



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